UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1064

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

Washington, D. C. ▼ August 21, 1922

OLEORESIN PRODUCTION

A MICROSCOPIC STUDY OF THE EFFECTS PRODUCED ON THE WOODY TISSUES OF SOUTHERN PINES BY DIFFERENT METHODS OF TURPENTINING

By

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Forest Products Laboratory

CONTENTS

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OLEORESIN PRODUCTION: A MISCROSCOPIC STUDY OF THE EFFECTS PRODUCED ON THE WOODY TISSUES OF SOUTHERN PINES BY DIFFERENT METHODS OF TURPENTINING.

A Thesis submitted to the Graduate School of the University of Wisconsin in partial fulfillment of the requirements for the degree of Doctor of Philosophy

by

ELOISE GERRY

Date MAY 31, 1921., 19....

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This thesis having been approved in respect of form and mechanical execution is referred to you for judgment upon its substantial merit.

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By ELOISE GERRY, *Microscopist, Forest Products Laboratory, Madison, Wis.*

CONTENTS.

THE NAVAL STORES INDUSTRY.

Naval stores is the name applied to the products obtained chiefly by distilling the oleoresin or gum which exudes from living pines when the wood is wounded. The turpentine and rosin thus obtained

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The writer wishes to express her appreciation of the many courtesies extended to her at the places visited in Mississippi, Louisiana, and Florida, and particularly to the following for assistance given in obtaining specimens and information on methods and practices:

The Bogalusa Turpentine Co., especially to Messrs. Adams, Kemp, A. T. Lewis, C. C. Harding, and N. T. Dorsey; Mr. J. P. Fraim, of the Fernwood Lumber Co., Fernwood, Miss.; Mr. J. F. Payne, Gulfport, Miss.; Mr. J. A. Taylor, of the Gillican-Chipley Co., the Union Naval Stores Co., the Imperial Naval Stores Co., Poitevent & Favre, all of New Orleans, La.; the Consolidated Naval Stores Co., of Jacksonville, Fla., especially Mr. McGarvey Cline; Mr. G. A. Clark, of Daytona; Mr. D. N. Corbett, of Orlando; Mr. A. Sessoms; and Mr. W. A. Sessoms, of Bonifay, Fla. Assistance was also generously given by the organization of the Florida National Forest, especially Capt. I. F. Eldredge, Supervisor L. L. Bishop, Deputy Supervisor E. R. McKee; also by Mr. Johnson and Mr. W. N. Hartgrove, of Garniers, Fla.; by Mr. Austin Cary, of the Washington office of the Forest Service; and by Mr. R. L. Pettigrew, Dr. A. W. Schorger, and Mr. H. F. Wiess, all formerly of the Forest Products Laboratory staff.

Helpful criticisms and suggestions were also given by Dr. C. H. Herty, editor of the Journal of Industrial and Engineering Chemistry, and by Prof. C. E. Allen and Prof. J. B. Overton, of the department of botany of the University of Wisconsin, as well as by members of the staff of the Forest Products Laboratory.

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have to-day supplanted pitch and tar, the chief products of this industy in colonial times in the United States.[1] But the descriptive name, naval stores, given when these commodities were used extensively in the construction and maintenance of sailing vessels, still persists. That mankind has long made use of these forest products appears from the descriptions of the production and uses of pitch contained in ancient writings.[2] As long ago as the fifth century before Christ, the pines of Macedon were a famous source of pitch. During the period 315 to 166 B. C., Macedon is recorded to have had a distinct monopoly of wood and pitch, which highly valued and important commodities could not be exported without special permission from the ruler.[3] Pitch was obtained by destructive distillation of the heartwood or of especially pitchy chips from wounded trees, or by driving off the water from the exuded gum. Pitch was in great demand for calking the seams of ships, including the war ships of the period, as is related in the case of the "wooden walls of Athens at Salamis." It was also used, for example, as a surface coating for altars and doors or as a sizing or lining for clay storage jars, used as containers for grain and other supplies.

Until rather recently many of the methods used in the early days of the industry in this country were still in vogue. The cup method, introduced on a commercial scale about 1904,[4] has, however, of late largely supplanted the wasteful box system. (See Pl. I, fig. 1.) Another much-needed improvement is seen in the tendency to reduce the amount of wood removed when the trees are scarified or chipped. The success of this practice has been demonstrated by experiments and the experience of progressive operators. In order to determine the best methods of turpentining, a comprehensive understanding of the tree's responses must be obtained. This involves thorough research of problems bearing on many aspects.

PURPOSE OF THE INVESTIGATION.

The investigation here described is concerned primarily with the comparison of the results of experiments with three different methods of chipping. It is shown that the success of a method can not be judged merely on the basis of the yield obtained. The maintenance of wood production, as indicated by growth in height and in diam-

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[1] Public Record Office, London, 1610. "Instructions for suche things as are to be sente from Virginia." Also "Booke of the Commodities of Virginia" (cited from U. S. Dept. Agr. Bul. 229.)

[2] Theophrastus: "Enquiry into Plants" III, IX, 1–3 and IX, II & III. Plini: Naturalis Historia XVI.

[3] Glotz, G.: "L'Histoire de Délos d'après les Prix d'une Denrée." Revue des Études Grecques. Tome XXIX. Juillet–Septembre, 1916. (Reviewed by Gerry, E. Jour. For. 19: April, 1921, p. 438.)

[4] Herty, C. H.: "The Turpentine Industry of the Southern States." Jour. Franklin Institute. March, 1916.

eter, and the preservation of the general health of the tree are considerations of fundamental importance. This is especially true with reference to the methods that are to be used in the future for turpentining smaller, second-growth trees. The need for wider knowledge and the practice of better methods is imperative in the United States, in order that this important and exceptional opportunity for the production of naval stores shall not be wiped out or wasted by improper exploitation.[5]

The work covered was undertaken in order to obtain, by means of microscopic study, information on the changes which result from turpentining in the wood of the pines, which are the chief sources of naval stores. The advantages and disadvantages of different methods of operation were determined chiefly by examining specimens of the wood produced near the faces or scars. These specimens were usually cut just above the streak or surface of the last wound. Structures found on workings of different ages were also studied. The specimens furnished evidence which served as a check of considerable precision upon the more general means of comparison, such as amount of gum produced and percentages of dead and dry-faced trees caused by turpentining. Changes produced by turpentining which were registered in the internal anatomy of the pines were studied, not only in the completed annual ring at the end of the season, but also particularly in specimens obtained periodically throughout the year. The first material was cut before wood formation began in the spring, and the development shown in fresh specimens cut each month thereafter was studied throughout the subsequent growing season. The chief source of material was a cooperative experiment carried on at Columbia, Miss., where three methods of chipping were compared,[6] but specimens were also collected at other points in Mississippi and in Louisiana and Florida.

An attempt was also made to determine the significance of certain observations made at the Forest Products Laboratory not in accord with views previously published, some of which were founded upon analogy rather than upon the study of native American species.[7]

OLEORESIN.

The exudation obtained by the systematic scarification of the living pines, especially longleaf pine in the United States, is variously known as "oleoresin," "gum," "dip," and "scrape" (when hardened after long exposure to the air). From this substance rosin

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[5] Approximately 75 per cent of the world's supply of gum turpentine is made in the United States.

[6] See pp. 12 to 25.

[7] Herty, C. H., "Relation of Light Chipping to the Commercial yield of Naval Stores," For. Ser. Bul. 90, 1911. Tschirch, A., "Die Harze u. d. Harzbehälter," 1900.

and turpentine are obtained as the products of distillation. The "gum turpentine" distilled from oleoresin is distinguished from "wood turpentine," which is obtained from the steam or destructive distillation of the resinous heartwood of stumps or dead or down timber.

Fresh gum spirits of turpentine distilled from the southern pines of the United States consists of several similar or closely related compounds known as terpenes, together with small and varying quantities of oxidized derivatives thereof.[8] The empirical formula of the terpenes is $C_{10}H_{16}$, indicating that turpentine consists almost entirely of carbon and hydrogen. Of the terpenes, the one known as pinene occurs in the highest proportion in spirits of turpentine. Alpha pinene is found to the extent of 80 to 85 per cent in the average pure, fresh, American gum spirits of turpentine. Among the other terpenes which have been found in small quantities in turpentine oil may be mentioned beta pinene, camphene, silvestrene, and dipentene, the last two being found also in destructively distilled wood turpentine. American pinene, the greater part of which is obtained from longleaf pine (*Pinus palustris*) gum, has optical properties different from those of the French. The pinene from slash pine (*Pinus caribaea*), however, resembles the French in this particular. Otherwise the turpentine oils of slash and longleaf pines are very similar, whether obtained from the wood or from the leaves.[9]

STRUCTURE OF WOOD OF TURPENTINE PINES.

Of fundamental significance for the understanding of the production of naval stores is the structure of the wood of the pine, especially of *Pinus palustris* Mill. (longleaf pine), and *Pinus caribaea* Morelet (slash pine), which are the chief turpentine pines of the southern United States and produce approximately 75 per cent of the world's supply of naval stores.[10] It is from the outer wood next the bark in the living pine that oleoresin is obtained. Here also the responses to turpentining, differing according to the methods practiced, are clearly registered in the woody tissue that is formed after the scarifications have been made.

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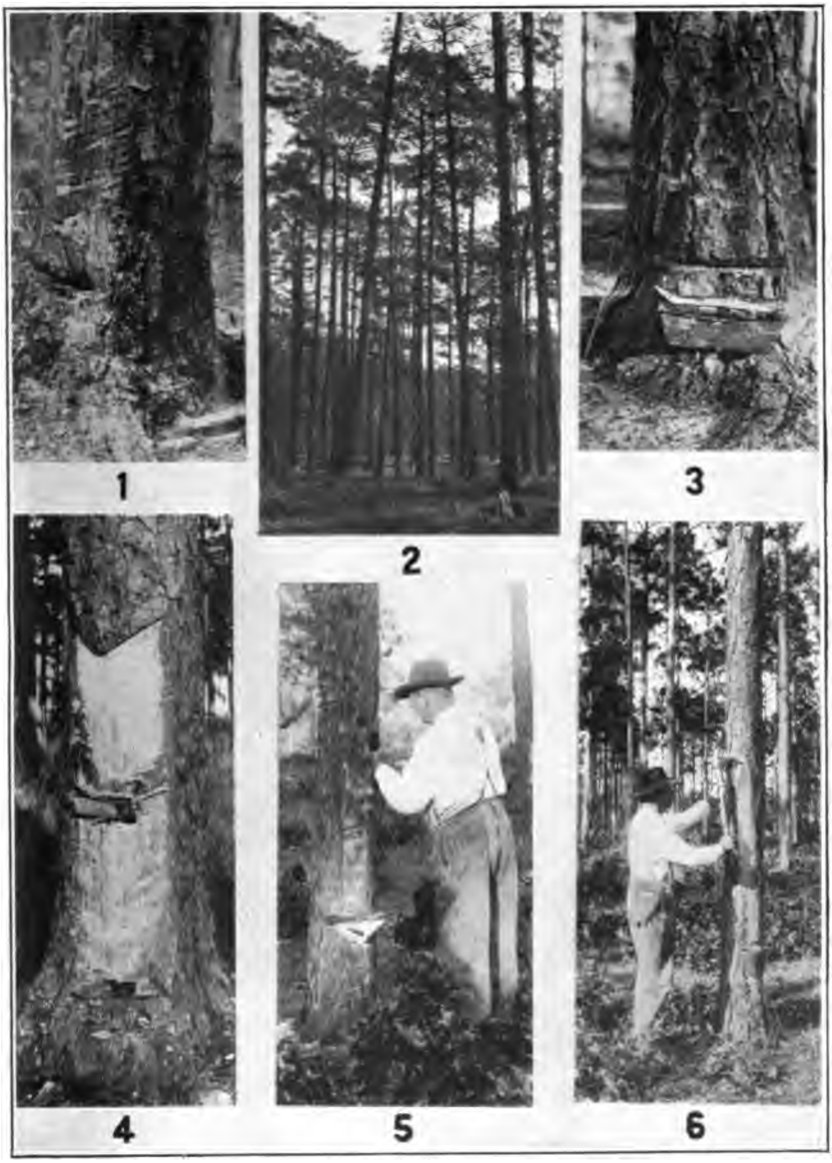
[8] Veitch, F. P., and V. E. Grotlisch, "Turpentine," U. S. Dept. Agr. Bul. 898, 1920.

[9] Schorger, A. W., "Constribution to the Chemistry of American Conifers." Trans. Wis. Acad. of Sci. Arts and Letters, 19: March, 1919, p. 742.

[10] Oleoresin is also obtained in relatively small quantities from various other species of pine, including: In the United States, *P. echinata*, shortleaf; *P. taeda*, loblolly; *P. ponderosa*, western yellow; and *P. serotina*, pond pine; in France, *P. pinaster* or *maritima*, maritime pine; in Greece and Algeria, *P. halepensis*, Aleppo pine; in Italy, *P. pinea*, stone pine; in Austria, *P. laricio*, *austriaca*, or *nigra*, black pine; in India, *P. longifolia*, chir pine; and *P. excelsa*, the Himalayan or Bhotan pine; in Mexico and Central America, *P. ayacahuite*, the Mexican white pine; in central Germany, Poland, and northern Russia, *P. silvestris*, Scotch pine; and in Japan, *P. thunbergii*, Japanese black pine. (From U. S. Dept. Agr. Bul. 898.)

PLATE I

FIG. 1.—The old method of cutting a box or cavity in the butt of the tree. Disadvantages: The tree was weakened; it became a fire hazard; the box was difficult to empty; and wasteful as a receptacle for receiving gum from a high face.
FIG. 2.—Stand which includes the trees selected from the narrow, double, and standard chipped tracts at Columbia, Miss., for detailed microscopic study throughout the respective seasons of 1916 and 1917. Note the presence of some suppressed trees.
FIG. 3.—The American practice of placing an "advance streak" some weeks before regular chipping begins. (This picture was obtained through the courtesy of Mr. F. Canning of the Forest Service of India.)
FIG. 4.—Appearance of a tree at the end of a standard 2-year commercial operation, at Columbia, Miss.
FIG. 5.—Small or modified American face used experimentally on small timber on the Florida National Forest after 3 years' turpentining.
FIG. 6.—French method of turpentining as practiced experimentally on small timber on the Florida National Forest after 3 years' turpentining. Note shape of face, chipping tool, and area freshened.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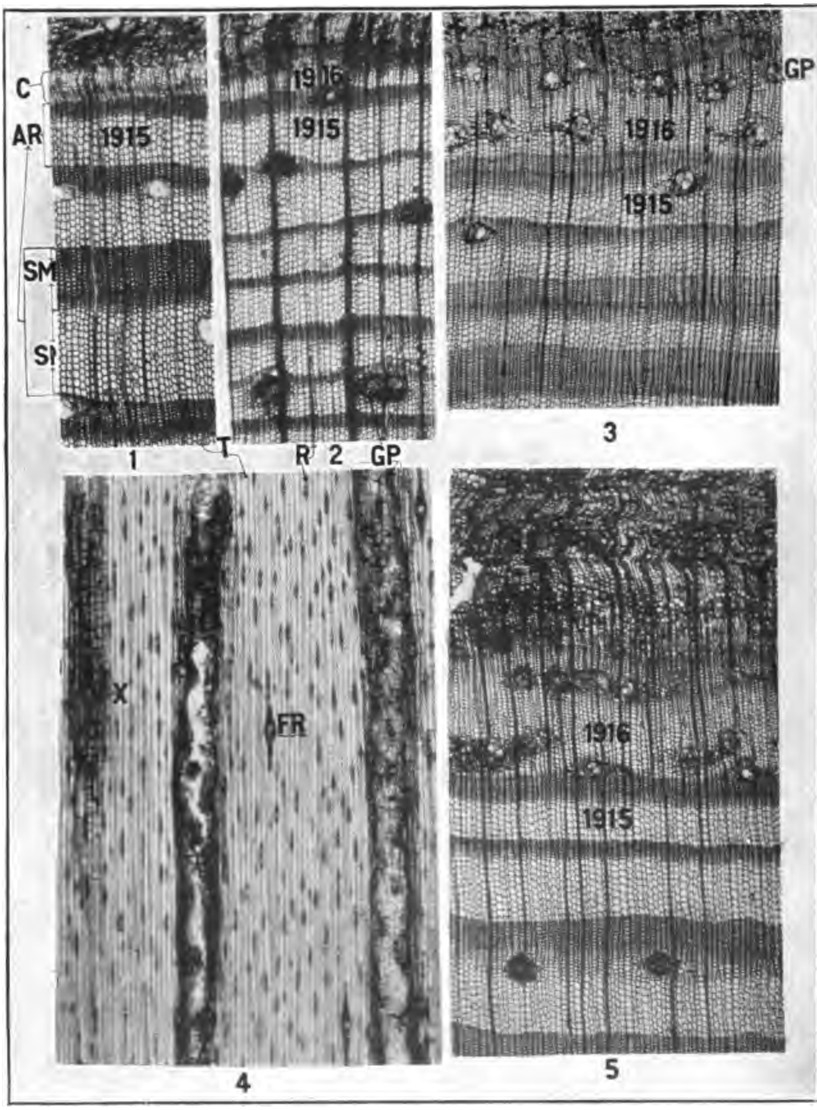
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PLATE II

In these specimens from a virgin or first-year operation at Columbia, Miss., 1916, the bark appears at the top of the figure in all except figure 4. The 1916 ring or its incipient formation is shown next the bark. All the other rings shown were formed by the trees before turpentining began.

AR, annual ring; SP, spring wood; SM, summer wood; T, tracheids or wood fibers; R, rays; and GP, groups of parenchyma cells or resin passages.

FIG. 1.—An example of the condition of the tree on April 13, 1916. No wood or resiniferous tissue had fully differentiated, but cambial activity (preliminary stages of wood formation) is apparent (at C) next the bark.

FIG. 2.—By June 13, 1916, at least 5 or 6 tracheids are apparent, and resiniferous tissue appears to be about to differentiate. In the first year several rows of wood cells usually formed before resin passages were produced.

FIG. 3.—Specimen cut July 5, 1916. Numerous resin passages present developed early in the annual ring. Compare size of passages in the 1916 ring with size of those in the other rings.

FIG. 4.—Tangential section through 1916 ring, showing longitudinal view of vertical resin passages (GP), formed in a turpentined tree. Also T, tracheids; R, ray parenchyma; FR, ray with horizontal resin passage; and X, a crossing of the vertical and horizontal resiniferous systems.

FIG. 5.—Specimen cut July 5, 1916. In the 1916 ring, forming next the bark, are tangential series including several resin passages. This very abundant formation of resin passages accompanies the wounding or turpentining. The exudation from these is shown in Plate III, figure 2.

Longleaf pine as found in the southern United States of America is the species chiefly discussed and illustrated in the following pages as the typical producer of American naval stores. Botanically, it is classed in the division of the Spermatophyta, the subdivision of the Gymnospermae, the order Coniferales, and family Pinaceae. The structure of the wood, the principal subject of this research, as seen with the aid of the microscope in an end view or cross section made from a normal unturpentined specimen, is shown in Plates II, V, and VI. The yield of oleoresin, obtained when a tree is wounded, comes from the cells of the aggregates *GP*, Plate II, figures 3, 4, 5, and elsewhere.

CAMBIUM.

The cells of the wood and bark of the pine are formed by the division and differentiation of the cells of the cambium layer, which is situated between the bark and the wood (*C*, Pl. II, fig. 1). This layer is made up of thin-walled cells, which retain their power to divide and thus produce the new cells composing the yearly rings of bark and wood, respectively.[11]

ANNUAL RINGS.

The layer of new wood formed each year on the outside of the woody core of a tree is known as an annual ring (*AR*, Pl. II, figs. 1, 2, 3, and 5.) In the pines in question it is conspicuously differentiated into two portions. The spring wood (*SP*) has thin-walled cells and large cavities, and forms early in the growing season. The summer wood (*SM*) has denser cell walls, and though it may begin to form as early as June, it generally develops in July, or, at the latest, August. The width of the annual ring and the amount and density of the summer wood formed are markedly influenced by turpentining, and serve as indicators of the effects of the various methods used.

SAPWOOD AND HEARTWOOD.

A varying number of the outermost annual rings of wood make up the sapwood. This is usually lighter in color than the heartwood, or central portion of the tree. The water solutions of the sap circulate through the sapwood, and it is in this region that the oleoresin exudes from certain cells (parenchyma) which are characteristically active. Each year a portion of the inner sapwood ceases to function and becomes dead heartwood; as a result the thickness of heartwood increases with the tree's age, but that of the sapwood remains, with relatively small variations, approximately the same. The walls of

[11] It is the cambium that tears when the wood is separated from the bark cylinder in making a willow whistle.

the older cells tend to become more or less impregnated with resin as they are transformed into heartwood, which serves primarily for mechanical support. The resin in the heartwood flows out much less easily than that in the sapwood, as may be seen on any freshly cut log or stump. Although the heartwood contains more resin by chemical analysis, it will not, if tapped, produce a sustained yield of resin, as the sapwood, if properly treated, will. Gum turpentine is obtained from a number of the outermost sapwood rings (Pl. III, fig. 2). The depth of the cut in relation to the width of the sapwood is a very significant factor with reference to both the yields obtained and the injurious effect of turpentining upon the tree. Successful turpentine operations depend upon keeping the sapwood in a healthy condition, capable of responding not only to normal stimuli but to the special wound stimuli as well.

TRACHEIDS.

During the growing season, April to November, the individual cells of the outermost annual ring of the sapwood, as they are derived from the cambium, become differentiated and develop into specialized structures. These are the tracheids. (T, Pl. II, figs. 1 to 5.) They are vertically extended cells which complete their formation and lose their protoplasmic content early. They then serve for sap conduction and finally for the mechanical support of the tree. They are not directly connected with oleoresin production, although they constitute a significant part of the organic mechanism of the tree. They differ somewhat in appearance, as was stated in the discussion of spring wood and summer wood (p. 5). The character of the summer wood tracheids and also the total number of tracheids formed often serve as indicators of the vitality and responsive power of the trees under observation.

PARENCHYMA.

The parenchyma tissue found in pines may be considered under two main heads: First, the horizontally extended parenchyma cells constituting the rays (*R*, Pl. II), including the fusiform rays (*FR*, Pl. II, fig. 4) with their horizontal resin passages; second, the vertically extended parenchymatous elements, which grouped together (*GP*, Pls. II, V, and VI), form the resin-producing centers, the so-called resin passages, ducts, or canals. The parenchyma cells are characterized by the fact that they "remain alive," that is, retain their protoplasmic content and function actively for a number of years or until approximately the time when the inner rings of the sapwood change into the heartwood.

It is both from the horizontally extended fusiform rays, as exposed on a freshly cut tangential surface, and the vertically extended parenchyma aggregates, as exposed on the cross section, at the streak, that the droplets of oleoresin may be seen to exude. Large nuclei are often to be seen in these cells, as well as accumulations of starch grains. Tannin is also reported to be associated with resin formation.[12] The vertical and horizontal systems of resin-producing parenchyma are more or less united, since they frequently cross each other. The method of turpentining which keeps these cells active and which provides suitable stimulation to insure their greatest productivity without undue injury will give the highest and best yield of oleoresin over a period of years. In the discussion in the following pages of the results from the experiments, the methods used were judged, not alone by the yield obtained, but also by the amount and type of the wood tissue produced, as indicative of the vitality and responsive power of the trees. In each case the wood tissue produced by neighboring, comparable, unturpentined trees growing under similar environment was studied and used as a check upon the judgments formed.

METHODS OF STUDY.

COLLECTION AND TREATMENT OF MATERIAL.

The first material to be studied was in the form of fresh chips or pieces collected by the writer from the living trees and put in corked bottles. This material was examined within a few hours after cutting. Specimens shipped to the laboratory at Madison periodically during the season were handled in the same way, with the exception that sometimes moistened cotton was put in the bottles to prevent the drying out of the specimens. Later, fixing solutions were used, and the chips or increment borings were placed in the solution selected as soon as cut. These were kept for a length of time which necessarily varied with circumstances, washed with water, and stored in glycerine and alcohol. The fixatives used were: (1) Mercuric chloride, a saturated solution in 90 per cent alcohol; (2) mixture of a saturated solution in 90 per cent alcohol of mercuric chloride (3 parts) and of picric acid (1 part); (3) chrome-acetic fixative, consisting of a mixture, in 100 cubic centimeters of water, of 1 per cent glacial acetic acid and 0.7 per cent chromic acid.

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[12] Haas and Hill: "'Introduction to the Chemistry of Plant Products,'' Vol. I, 3d Ed. 1921. pp. 195, 217. '" In *Pinus* it is stated that the amount of tannin varies with that of the resin; thus in the spring it was found that as the tannin decreased in amount so the resin increased. * * * That starch frequently is contained in the same cells with tannin suggests a connection between the two and it is not impossible that the starch may contribute glucose for the constitution of the tannin. The cells surrounding the epithelium of resin ducts contain tannin and starch." Wiesner "Die Rohstoffe des Pflanzenreiches" concluded that tannin was an intermediate product in resin formation.

SECTIONING AND MOUNTING.

Relatively thin sections (10 to 48 microns) were made from the greater number of the specimens studied. For this purpose a sliding microtome of the Jung type with the Thomson modification was used. Some observations were made with a hand lens on smoothly cut surfaces. The sections to be preserved or photographed were stained with safranin (water-alcohol mixture), dehydrated with alcohol, cleared with xylol, and mounted in Canada balsam. Microscopic examinations were also made of microtome or hand sections temporarily mounted in glycerine alcohol (50-50 mixture).

AMOUNT OF MATERIAL.

Samples were obtained each month during the 1916 and 1917 seasons, from 15 trees, 5 from each of the three experimental plots.[13] Specimens were also examined at the end of each season from 50 trees on each plot and from 50 unturpentined trees from the same locality. In addition to this, considerable material was collected from Bogalusa, La.; Kokomo and Gulfport, Miss.; Daytona, Bonifay, and the Forest Service experiments and leases near Camp Pinchot, Fla. More than 4,500 microscopic mounts were prepared and examined.

PROCESS OF TURPENTINING.

METHODS OF WOUNDING OR SCARIFYING THE TREES.

In ordinary methods of turpentining the oleoresin is made to flow from the tree by periodically cutting a wound or streak through the bark and for a variable distance into the sapwood. In the United States the cut or streak is generally made in the form of a somewhat flattened V, the point or peak of which is at the center of the face. (Pl. I, fig. 4.) The wound used by the French is different in shape (Pl. I, fig. 6), and smaller. The Germans recently have been practicing modifications of the American system.

Except for the general type of face used, the commercial practice of turpentining is not standardized in the United States. The size of the faces used, the amount of bark bars between faces, and the dimensions of the streak or wound cut each week, show marked differences in different operations. The depth of the weekly chipping may vary from one-half inch to 1¼ inches (bark not included), and the height of the chipping from one-half inch to 1 inch, or enough, as some operators say, to "keep ahead of the lightwood."[14]

[13] When more than one face was on a tree each face was indicated by a letter descriptive of its general position with reference to points of the compass, as N., S., E., W. (See, for instance, tree 1, fig. 1.)

[14] See p. 31.

It is customary to cut from 28 to 40 streaks each season. Often one-third of the trees in a commercial operation die, chiefly because of the undue severity of the methods used in turpentining. In some places the old method of cutting boxes or cavities at the butts of the trees (Pl. I, fig. 1) to hold the exuding gum, is still used, although, for the most part, cups of various types are employed (Pl. I, figs. 1, 3, 5, and 6).

After chipping, the gum or oleoresin exudes from the freshly cut surface. The most abundant exudation (88 per cent) has been observed to occur during the first three days after chipping. (Table 1.)

TABLE 1.—*Rate of exudation of gum from chipped longleaf pine.*[1]

Day.	Grams of gum.	Total exudation, per cent.
First	113.0	67.26
Second	22.5	13.39
Third	13.5	8.04
Fourth	9.0	5.36
Fifth and sixth	9.0	5.36
Seventh	1.0	.59
Total	168.0 (=0.37 lb.)	100.00

[1] For. Serv. Bul. 90, p. 6.

SIGNIFICANCE OF RESIN PASSAGES PRESENT IN THE UNTURPENTINED TREES.

The gum which exudes during the first weeks of a virgin or first-year operation comes from the normal resin passages which were already present in the round or unturpentined timber. Plate II, figure 1, shows the characteristic condition of the trees at Columbia, Miss., on April 13, 1916. At that time no new wood or resiniferous tissue for the 1916 ring had formed. Plate II, figure 2, shows a cross section cut from a tree on June 13, 1916. The development of new wood cells is apparent, and new resiniferous tissue may be seen to be differentiating in the region next the cambium. Plate II, figure 3, shows a cross section cut from a tree on July 5, 1916. Marked differences between individual trees occurred, however, and the range of development of the 1916 ring shown in the three figures might be encountered in material cut at the same time from different trees during either late May or early June. Often it is the end of May before the new and augmented development of the resiniferous tissue, formed after wounding in the new wood, is sufficiently advanced to yield appreciable amounts of resin. Indeed it frequently happens that in a virgin operation the normal resin passages present in the round timber may fill the cups not only for the first but also for the second and sometimes for the third time, or "dipping," before any new resin

passages are differentiated in the annual ring beginning to form for that year. An instance of a yield obtained by the end of April, ranging from 16 to 24 barrels of gum per month, per 10,000 cups, or "crop," was observed on a virgin operation where at the time no new resiniferous tissue had been formed. *Therefore it is apparent that the resin passages already present in the outer sapwood of the round timber play a significant part in producing the gum obtained.*

USE OF THE "ADVANCE STREAK."

A practice, the consequences of which are as yet not fully explained, but which appears to produce desirable results, is that of cutting a streak or wound some time before regular chipping begins.[15] The results of such scarification were pointed out by Dr. C. H. Herty in 1911. In the early experiments, made to demonstrate the advantages of replacing the box system by the cup system, the boxes were cut in winter and cornered in late winter. The first streak was made somewhat later along the upper edge of the wound made by cornering. In the case of the cupped trees, on the other hand, no such severe wound was inflicted. The trees, however, were cornered—that is, the bark and some of the wood were removed in order to obtain a suitable surface for the gutters. The first streak was cut at a little distance above the curved rim of the cornered surface. The ends or corners of the streak were farther above the cut surface than the peak and consequently did not reach directly to this open wound made some time before. Until May the yield of gum was notably less in the cupped trees than in the boxed trees, which had received a more intense wound stimulus.

Wounding the outer sapwood, therefore, in this manner (or even less severely, as is the practice on the Florida National Forest and in India) appears to have a very definite effect on the early yield of gum. It was estimated by one operator, for instance, that this practice gained for him, on one operation, a total of $500,000 in one year.[16] This practice, strongly advocated by Dr. Herty, was repeatedly employed with success. The theoretical explanation of it, advanced by him on the basis of the results of Tschirch's[17] investigations on other resin-yielding trees, was however not in accord with the facts. His deduction was as follows:

> Immediately after cornering (late winter) the formation of secondary resin ducts begins at all points of the cut. Later when the tree is chipped, these secondary ducts are opened along the full length of the cut and a good yield is consequently at once obtained.[18]

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[15] For. Serv. Bul. 90, p. 28.

[16] Herty, C. H., "The Turpentine Industry in the Southern States." Jour. Franklin Institute, March, 1916, p. 362.

[17] See footnote p. 3.

[18] For. Serv. Bul. 90, p. 28.

As has been shown, no induced resin passages were present and no wood formation occurred until the latter part of April. Consequently this increased early yield came from the induced responses of the resin passages already present in the round timber. These apparently were stimulated to greater activity by the advance streak than would have been produced by ordinary chipping later in the season.[19]

Observant operators were often aware of the fact that men who started operations with a little chipping very early in the season generally obtained high yields. The following statement by a practical man, whose family has been in the turpentine business for four generations, bears directly upon this point:

> It has been a matter of common experience with everyone familiar with turpentining that with a box cut late in the season, followed by chipping immediately thereafter, the yield of gum is very little for the first two or three months of the season. * * * If you chip any face at one time 3 inches up, the face will not run well for two or three months following.[20]

Apparently the region just above the wound is profoundly influenced by it, but the response may not be apparent at once. This idea is incorporated in the standard Forest Service practice on the Florida National Forest, where it is the custom to cut one streak when the aprons (metal strips used instead of gutters) are placed; that is, the streak is cut some weeks in advance of the regular chipping. (See Pl. I, fig. 3.)

The influence of the advance streak is not only a factor in the case of the response of the ordinary resin passages, formed in the round timber, but is also probably manifested in the amount and responses of the resiniferous tissue found in the new wood which is formed as the season progresses. Similar responses may underlie the following observation, namely, that in the second year of the turpentine operation resiniferous tissue occurred somewhat earlier in the new growth ring than it had in the first year of the operation. Some experiments on obtaining the gum storax from red gum trees also appear to show a somewhat analogous situation.[21] These trees, which normally have no resin passages, develop them as a result of wounding. In the case of red gum trees which were wounded as late in the spring as May 30, the first response in the developing annual ring was the formation of normal wood. It was from four to six weeks later that the formation of functioning resin passages, as indicated by the presence of any considerable amount of gum exudation,

[19] Since this was written it has been learned that the advance streak is recognized as essential in turpentine practice in India.

[20] Courtesy of Mr. A. Sessoms, of Bonifay, Fla.

[21] Gerry, E., "American Storax Production," Jour. For. 19: January, 1921.

occurred. Here, as in the case of the pines, and even in that of the conifers studied by Tschirch in midsummer condition, considerable time was required to obtain the major response induced by the wound.

PART PLAYED BY RESIN PASSAGES FORMED AFTER WOUNDING.

When the new wood formation begins after wounding, one of the most striking features of the developing ring is the early differentiation of more resin passages than are normally found. As soon as these resin passages, induced by wounding, are formed, they add materially to the flow of oleoresin, since they are generally very numerous (Pl. II, fig. 3) and are often arranged in rather continuous tangential series (Pl. II, figs. 3 and 5). Although a considerable amount of gum comes from this newly formed resiniferous tissue, it seems doubtful if, as has been stated, it constitutes "the chief source of commercial crude turpentine."[22] The term "secondary resin passages" has been used to describe the resiniferous tissue formed in the annual rings after turpentining. In contrast to this the term "primary resin passages" has been applied to the resin passages present in the round timber. Both these terms seem undesirable, inasmuch as the distinction between the resin passages of the two regions is not clearly defined, and since a certain number of the so-called primary passages would have been present under any circumstances in the new wood. Which these are, it would be impossible to determine. The types of resin passages found will be discussed with reference to length and number in the following pages.

RESULTS OBTAINED BY DIFFERENT METHODS.

EXPERIMENTS AT COLUMBIA, MISS.

STANDARD PRACTICE.

The operating methods termed "standard" in this report are the regular methods practiced by the company with which the cooperative experiment here described was carried on. The chipping was somewhat heavier than that known as the standard Forest Service method. In the Standard chipping as practiced at Columbia, Miss., the streaks were cut with a No. 2 hack or chipping tool. (See Pl. IV, fig. 2.) The weekly streak varied in depth from one-half to three-fourths inch and was about one-half inch in height. The type of forest, as indicated in Plate I, figure 2, consisted of large mature timber, but included also many old but relatively small suppressed trees. The chipping began early in the spring of 1916. The first material for microscopic study was collected in April, after four or five streaks had already been cut. The yield from

[22] For. Serv. Bul. 90, p. 27.

about 5,300 cups, operated by this method, was separately recorded, so that it could be compared with the yield obtained from the trees on similar stands of timber adjacent, which were operated by the two special methods under experiment.

This operation was carried on for a period of two years. Figures 1 and 2 give the monthly observations on the five trees selected in 1916 and in 1917 (not the same five trees both years). The number of tracheids counted in a radial direction across the ring indicates the diameter increase since the beginning of the year. The fluctua-

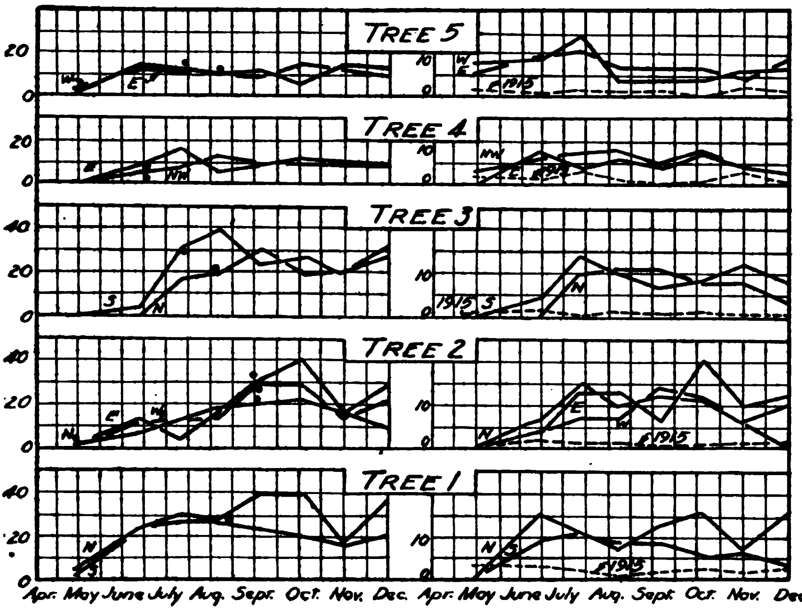


FIG. 1.—Standard trees, 1916.

Number of tracheids, observed April to December; in 1916, growth ring. °Summer wood present.

Number of resin centers per unit area (an arbitrary tangential extent; diameter of microscopic field by the width of the annual ring observed). Observed April to December, 1916; in 1916, growing ring; in 1915, completed ring.

tions in the number of resin passages present are also shown. In Tables 2 and 3 are given the relative increases and decreases in width of annual ring and percentage of summer wood as observed in December, 1916, in 50 trees chipped by each of the three methods under observation and in 20 unturpentined trees. In Table 4 are given similar observations for the years 1915, 1916, and 1917.

In 1916 considerable variation was found in the number of tracheids observed from month to month in the specimens from the five selected trees. (Fig. 1.) The width of the 1916 annual ring in the specimens cut near the end of the season was in several cases

less than that observed at lower levels earlier in the year. The number of resin passages per unit area [23] also was often smaller at the end of the season, but was throughout larger than that in the round timber. In 1916 this material was taken wherever a good chip chanced to be cut along the streak.

In 1917 care was taken to cut the specimens midway between the peak and the corner in all cases. By comparing figures 1 and 2, it is apparent that marked variations occurred, nevertheless, in the

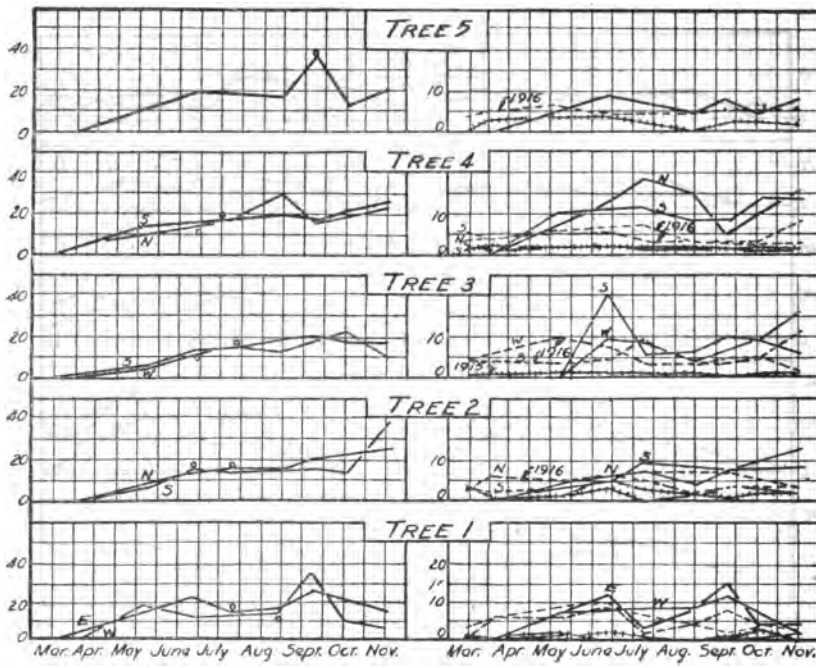


FIG. 2.—Standard trees, 1917.

Number of tracheids, observed March to November; in 1917, growth ring. ° Summer wood present.

Number of resin centers per unit area (an arbitrary tangential extent; diameter of microscopic field by the width of the annual ring observed). Observed March to November, 1917; in 1915, 1916, and 1917, growth rings.

1917 material. Consequently these variations may be considered as characteristic of the annual ring, whether studied in the same or in different parts of its circumference and at different heights in the tree. During 1917, furthermore, many more resin passages than were normally found were produced, but at the levels where

[23] An arbitrary unit made up of the portion of the annual ring in question which could be included in a microscopic field of a given magnification, the diameter of which was moved so as to include the approximate rectangle bounded by the beginning and end of the annual ring.

the 1917 material was cut it was obvious (fig. 2) that the number of resin passages present by June or July in the 1917 ring was greater than in the 1916 ring; and at no time in 1917 was the maximum number of resin passages in the 1916 ring as great as the maximum number in the 1917 ring. If, on the other hand, the number of resin passages present in the July, 1916, material cut in 1916 (fig. 1), is compared with the 1917 material cut in 1917, it is apparent that approximately similar numbers of resin passages were present.

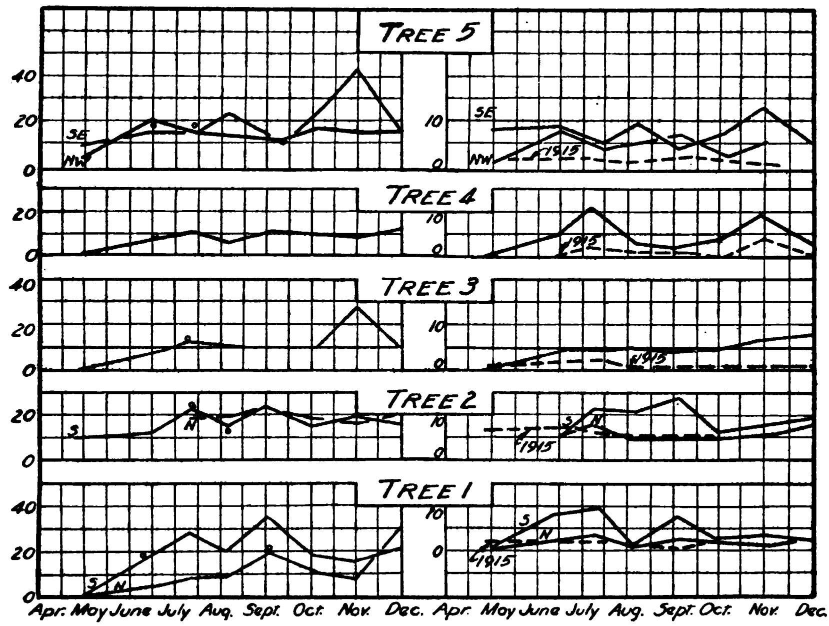


FIG. 3.—Double trees, 1916.

Number of tracheids, observed April to December; in 1916, growth ring. ° Summer wood present.

Number of resin centers per unit area (an arbitrary tangential extent; diameter of microscopic field by the width of the annual ring observed). Observed April to December, 1916; in 1916, growing ring; in 1915, completed ring.

The conclusion therefore seems justified from this and other data that some of the resin passages are shorter than others, and are entirely cut away as chipping progresses. The microscopic observations indicate that in the case of the standard tract, the trees, judged by their wood formation in the neighborhood of the faces, a region where the wound response is very pronounced, did not suffer seriously from the effects of turpentining by this method for a two-year period. The wood formation was reduced more than in the case of the narrow chipping, as is brought out in the comparisons given in Tables 2 to 4. From Table 2, for instance, it is apparent that in

1916 many trees, 36 to 78 per cent, according to the position from which the material was taken, showed no decrease in ring width following turpentining. Also (see Table 3) 26 to 64 per cent showed no decrease in the amount of summer wood formed, and the summer wood appears to be one of the most readily affected structural features. In Table 4, covering both 1916 and 1917, similar results were shown; but the decreases in 1917, the second year of the operation, are somewhat larger in the case of this type of chipping than they were in 1916. The size of the resin passages also decreased somewhat as time went on. On the average a greater number of resin passages per unit area was formed on this tract in 1917 than on the double tract. In both 1916 and 1917, however, the number on the narrow tract exceeded that on the standard.

TABLE 2.—*Comparison of the annual rings formed in round timber (1915) and turpentined timber (1916).*

Number and kind of specimens.	Trees showing increase in ring width, 1916 (percentage of total number).			Trees showing no decrease in ring width, 1916 (percentage of total number).			Trees showing decrease in ring width, 1916 (percentage of total number).		
	Chips.	Increments.	Average.	Chips.	Increments.	Average.	Chips.	Increments.	Average.
20 trees untapped	....	70	70	....	95	95	....	5	5
50 trees narrow [1]	64	60	62	64	82	73	36	18	27
50 trees standard	26	56	41	36	78	57	64	22	43
50 trees double	44	50	47	58	76	67	42	24	33

[1] The narrow specimens showed more resin centers in the *chips* than were apparent in the standard and double specimens.

NOTE.—The *increment borings* were made on the tree at a distance of 2 to 3 inches from the face and at the same height as the last streak. The *chips* were obtained at the cutting of the last streak.

TABLE 3.—*Comparison of the amounts of summer wood formed in the round timber (1915) and the turpentined timber (1916).*

Number and kind of specimens.	Trees showing increase in amount of summer wood, 1916 (percentage of total number).			Trees showing no decrease in amount of summer wood, 1916 (percentage of total number).			Trees showing decrease in amount of summer wood, 1916 (percentage of total number).		
	Chips.	Increments.	Average.	Chips.	Increments.	Average.	Chips.	Increments.	Average.
20 trees, untapped	....	70	70	....	75	75	....	25	25
50 trees, narrow [1]	54	44	49	60	70	65	40	30	35
50 trees, standard	20	50	35	26	64	45	74	36	55
50 trees, double	26	28	27	38	44	41	62	56	59

[1] The narrow specimens showed more resin centers in the *chips* than were apparent in the standard and double specimens.

NOTE.—The *increment borings* were made on the tree at a distance of 2 to 3 inches from the face and at the same height as the last streak. The *chips* were obtained at the cutting of the last streak.

TABLE 4.—*Comparison of ring width, summer wood, and resin passage formation for 1915, 1916, and 1917.*

Operation.	Number of trees examined for—		Amount of wood formed.				Average resin centers per one-eighth inch cross section (Nov. 17, 1917).[1]					
			1916 compared to 1915.		1917 compared to 1915.		1915		1916		1917	
	1916	1917	Total ring.[2]	Summer wood.[2]	Total ring.[2]	Summer wood.[2]	No.	Size.	No.	Size.	No.	Size.
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*						
Standard chipping.	102	52	−34.0 +66.0	−51.5 +48.5	−56 +44	−67 +33	1.5	Medium	4.4	Largest.	8.3	Smallest.
Double chipping	108	55	−43.0 +57.0	−63.0 +37.0	−58 +42	−56 +44	1.2	...do.....	3.8	...do.....	6.4	Do.
Narrow chipping.	101	51	−35.5 +64.5	−41.5 +58.5	−45 +55	−45 +55	.8	Smallest	4.7	...do.....	9.3	Medium.

[1] In 1916 material it was noted that the narrow had more resin centers than the standard or double.
[2] Minus sign (−) indicates decrease in width; plus sign (+) indicates same width or increase in width.

TABLE 5.—*Comparison of yield data for 1916 and 1917.*[1]

Plot.	Year.	Corrected number of faces or cups.	Total dip distilled.	Total rosin.	Total turpentine.	Calculated yield per crop (10,000 cups).	
						Rosin.	Turpentine.
			Pounds.	*Pounds.*	*Gallons.*	*Pounds.*	*Gallons.*
Standard	1916	5,405	63,926	64,822	2,002.5	119,929	3,704
	1917	5,335	70,275	54,595	1,625.0	102,334	3,046
Narrow	1916	6,105	61,062	59,874	1,853.0	98,073	3,035
	1917	5,977	77,776	58,680	1,761.0	98,176	2,946
Double	1916	3,062	42,687	43,766	1,301.0	142,932	4,248
	1917	3,020	50,805	36,670	1,091.0	121,424	3,613

Plot.	Year.	Comparison of yields on the percentage basis.							
		Standard for respective years rated as 100 per cent for the given year.[2]				1916 yield for each crop rated 100 per cent for that crop.[2]			
		Rosin.		Turpentine.		Rosin.		Turpentine.	
		Pounds.	*Pounds.*	*Gallons.*	*Gallons.*	*Pounds.*	*Pounds.*	*Gallons.*	*Gallons.*
Standard	1916	100	....	100	....	100	....	100	....
	1917	100	....	100	....	85.4	−14.6	82.2	−17.8
Narrow	1916	81.7	−18.3	81.9	−18.1	100	....	100	....
	1917	95.9	− 4.1	96.7	− 3.3	100.1	+ .1	97.1	− 2.9
Double	1916	119.1	+19.1	114.6	+14.6	100	....	100	....
	1917	118.6	+18.6	118.7	+18.7	85.0	−15.0	85.2	−14.8

[1] Compiled from monthly field reports for 1916 and 1917.
[2] Minus (−) indicates loss; plus (+) indicates gain.

TABLE 6.—*Comparative yields per crop (10,000 cups) with respect to height of face (inches), 1916 and 1917.*[1]

Plot.	Year.	Height of face.	Number of streaks.	Average height of streak.	Turpentine.				
					Total yield per crop.	Yield per inch of face height.	Increase in percentage (standard rated 100 per cent).	Comparison of percentage (year 1916 rated 100 per cent).[2]	
		Inches.		*Inches.*	*Gallons.*	*Gallons.*			
Standard	1916	21.95	38	0.58	3,704	169	....	100.00	....
	1917	20.00	39	.51	3,046	152	....	90.00	−10.0
Narrow [3]	1916	[3] 12.85	38	[3].34	3,035	236	39.6	100.00	....
	1917	13.00	38	.34	2,946	227	49.4	96.2	− 3.8
Double [3]	1916	[3] 23.67	70	[3].34	4,248	179	5.8	100.00	....
	1917	19.00	72	.26	3,613	190	25.0	106.2	+ 6.2

Plot.	Year.	Rosin.				
		Total yield per crop.	Yield per inch of face height.	Increase in percentage (standard rated 100 per cent).	Comparison of percentages (year 1916 rated 100 per cent).[2]	
		Pounds.	*Pounds.*			
Standard	1916	119,929	5,463	....	100	....
	1917	102,334	5,117	....	93.5	−6.5
Narrow [3]	1916	98,073	7,632	39.7	100	....
	1917	98,176	7,552	47.6	98.9	−1.1
Double [3]	1916	142,932	6,039	10.5	100	....
	1917	121,424	6,391	25.0	105.9	+5.9

[1] Compiled from monthly field reports for 1916 and 1917.
[2] Minus (−) indicates loss; plus (+) indicates gain.
[3] The narrow and double areas had four standard streaks before the experiment started. The height of the four streaks averaged 2.75 inches (average from 25 measurements). With this allowance, the streaks on the narrow and double areas averaged 0.30 and 0.32 inch, respectively. The corrected height for the double faces is 22.20 inches and for the narrow faces 11.38 inches, which, in this latter case especially, would further improve its rating.

The comparative yields obtained are given in Tables 5 and 6. It is apparent that the total yield from the 1916 chipping was highest in the case of the double tract and lowest in that of the narrow. If, however, the narrow is compared to the standard with reference to height of face chipped, it is apparent that the narrow shows a gain of almost 40 per cent in the first year of the operation. During 1917, the second year of chipping, the results were even more strongly emphasized. The double showed about the same increase in total yield over the standard, but the narrow made a better relative showing than the year before, and nearly equaled the standard in total yield. With reference to the height of face, i. e., amount of chipping surface used to obtain the yield, the narrow showed almost a 50 per cent gain over the standard in yield per inch of height of face chipped.

In the second year in all crops there was some decrease in total yield. The 1917 comparisons, using the total 1916 yields from a crop as 100 per cent or the criterion for judging the relative yield of that crop, showed that the greatest decrease occurred in the standard tract. (Table 5.)

DOUBLE CHIPPING.

The special feature of this method, used for two years on this area at Columbia, Miss., was that the streak was cut at four-day intervals instead of only once each seven days. This type of chipping was used (Pl. IV, figs. 3, 5, and 6) on about 3,000 faces on the same kind of timber as that in the standard experiment. Only as much wood as was cut in the standard chipping was removed by this double method, since the dimensions of the streak specified were one-half inch deep and one-fourth inch high, cut twice weekly. The depth in general tended to average slightly less in the double than in the standard. During 1916 the chipping was carried on with a "00" hack (Pl. IV, fig. 2) and a streak averaging 0.32 inch was obtained (Table 6, footnote). In 1917 a "puller" (Pl. IV, fig. 6) was used, and a more accurate narrow chipping or rather "pulling" was obtained (average 0.26 inch) as is indicated in Table 6. This was also more accurate chipping than was obtained in 1917 on the single narrow-chipped area (average height of streak 0.34 inch), where a hack was used. It is of considerable interest to note that with this narrow chipping the double showed a smaller relative reduction in the second-year yield of turpentine, when compared to that of its first-year yield, than was shown by the wider-chipped (one-half inch per streak) standard. This was true in spite of the fact that the vitality of the double-chipped timber had apparently suffered rather more severely from the process of turpentining than had the standard.

In figures 3 and 4 are given the monthly observations on the five trees selected from the double area for 1916 and 1917, respectively (different sets of five each year). The same reduction as in the case of the standard was noted in the number of resin passages per unit area of the 1916 ring, as was observed in material cut at the level of the 1917 chipping. The tendency for fewer resin passages to be present at the end of the 1917 season than in midsummer was also observed. In 1917 practically all five trees from the double area showed that their wood formation had suffered as a consequence of that method of turpentining, and that they had not been able to recover, as many of the narrow-area trees had, or even been able to hold their own during 1917, the second year of turpentining, as some of the standard-area trees appeared to have done.

The results from the examinations of the 50 specimens collected at the end of the season each year are given in Tables 2, 3, and 4. In

Tables 2 and 3 results are given from a set of chips obtained at the last streak cut and a set of increment borings made 2 to 3 inches to the side of the face at the height of the last streak. The borings, in general, showed less effect from the turpentining than the chips, indicating that the response to the wound was not as marked tangentially or circumferentially as it was vertically. The double and the standard both showed more reduction in wood formation than the narrow, as indicated by ring width. Judged by the borings alone, the double showed slightly greater reduction than the standard. The chips, on the other hand, showed more reduction in ring width in the standard than in the double. This tendency, however, did not hold for the

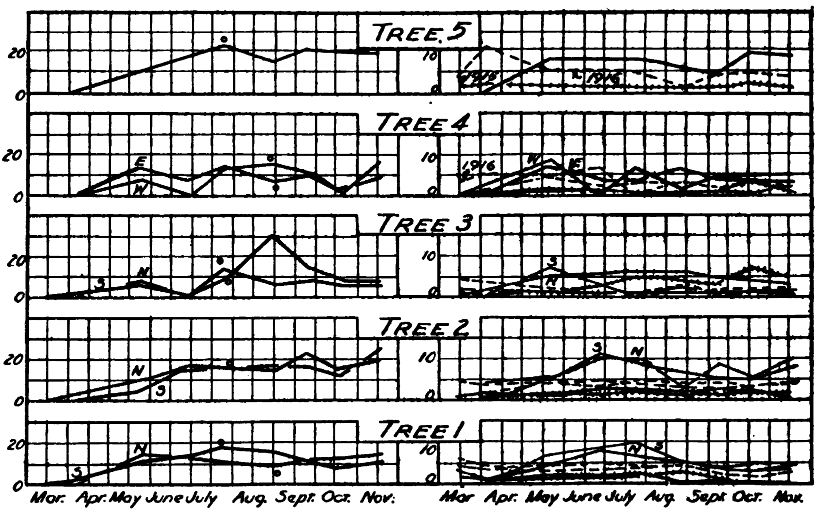


FIG. 4.—Double trees, 1917.

Number of tracheids, observed March to November; in 1917, growth ring. ° Summer wood present.

Number of resin centers per unit area (an arbitrary tangential extent; diameter of microscopic field by the width of the annual ring observed). Observed March to November, 1917; in 1915, 1916, and 1917, growth rings.

amount of summer wood present, which was exceptionally reduced in the specimens from the double tract. It would appear that the double chipping produced a special response which was manifest in the increased ring width shown by the chip specimens and in the sustained relatively high yield for the second year, which has been mentioned. It would seem, however, that this response was accomplished at the expense of summerwood production and of the tree's vitality in general, judging by such indications as these and by the frequent occurrence of "dry" faces in this crop. The double also produced fewer resin passages than the narrow. In 1917 (Table 4) the reduction in wood formation in the specimens collected from 50

87404°—22——4

PLATE III

FIG. 1.—A face from the double-chipped area, Columbia, Miss., in November, 1917, at the end of a 2-year operation. Tree freshly chipped, dry-facing beginning at peak, gum exuding well at shoulder or corner. Droplets indicate the position of resin passages.

FIG. 2.—A face from the narrow-chipped area, Columbia, Miss., in November, 1917, at the end of a 2-year operation. Tree freshly chipped. Abundant exudation all along the streak. Each droplet at a resin passage, clusters and lines of droplets indicate series of resin passages. Fourteen or more annual rings of sapwood exposed and participating in the yield.

1

2

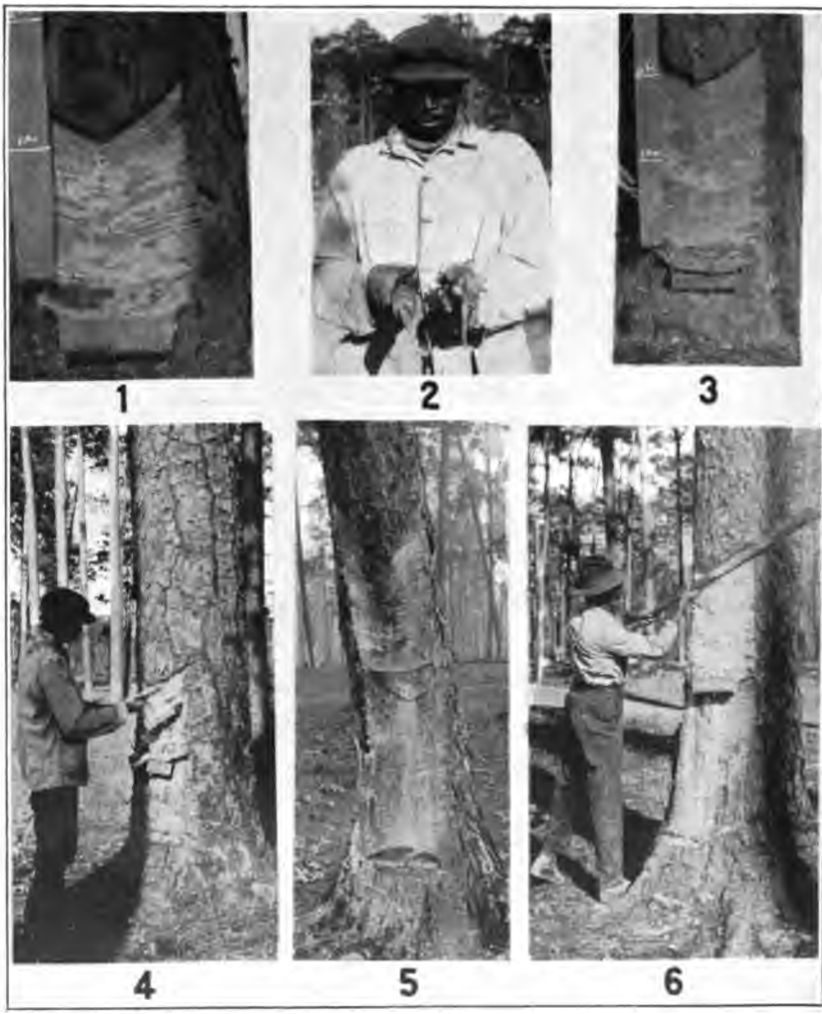

1
2
3
4
5
6

PLATE IV

FIG. 1.—Face from narrow-chipped area at the end of the first year of turpentining (1916). About one foot in height of chipping surface used.
FIG. 2.—The hack to the left of the picture is a "00." This type was used in the narrow and double chipping at Columbia, Miss. The broad "billed" hack to the right is a "No. 2," the type used in the standard chipping at Columbia, Miss.
FIG. 3.—Face from the double-chipped area at the end of the first year of turpentining (1916). About two feet in height or twice as much chipping surface was used here as in the case of the narrow chipping. (Compare figure 1.)
FIG. 4.—Low face on narrow chipping at end of second year of turpentining (November, 1917). Note paddle over cup to keep out trash.
FIG. 5.—A dry face. A considerable number of trees on the double-chipped tract at Columbia, Miss., showed dry faces during the second year of the operation, indicating reduced vitality of trees.
FIG. 6.—Relatively high face on the double-chipped area at the end of the second year of turpentining (same height as standard chipping). Note chip-catcher attached to puller. Somewhat higher yields may be obtained by this method in short operations.

trees from the double area at the end of the season was more pronounced than that of the year before.

The yields from the double area presented in Tables 5 and 6 show that a higher total quantity of gum was obtained by this method than by either the standard or the narrow chipping. From Table 6 it is also apparent that under the careful narrow "pulling" practiced in 1917 there was a marked gain over 1916 in yield, with reference to amount of face used. A slightly higher relative proportion of turpentine, as compared with rosin, was obtained by this method in both 1916 and 1917. It is questionable, however, whether the extra yield obtained is sufficient to justify the cost of the extra chipping, especially since the microscopic investigations showed that the responses of the trees on the double area, as expressed in the reduction of wood formation (Tables 2 and 3) and in the somewhat more belated and less abundant formation of resiniferous tissue, particularly in the spring of 1916, were less satisfactory than the responses obtained with the other methods of turpentining. Yet if a case occurs in which timber can be turpentined only for a short period (one or two years) before it is cut, this method might deserve consideration, especially if practiced only during the height of the producing season.

NARROW CHIPPING.

Narrow chipping was practiced on about 6,000 faces at Columbia, Miss., for a period of two years. The results obtained gave information worthy of careful consideration and further test, since they indicated a means of securing a high sustained yield for a considerable number of years with a comparatively small reduction in the vitality of the trees turpentined. The streak specified was of the same dimensions (one-half inch deep and one-fourth inch high) as that used on the double area, but it was cut only once each week. The type of forest was the same as that turpentined by the standard and double methods. Figures 5 and 6 show the results obtained from the monthly observations on the five trees selected for 1916 and 1917, respectively. Tables 2, 3, and 4 show the results of observations on larger numbers of specimens obtained at the end of the season each year.

Yields from narrow chipping.—The summarized yield data for 1916 and for 1917 are given in Tables 5 and 6. During the second year of operation the narrow crop produced within 4 per cent of the total yield of the standard crop, although during 1916, the first year of the operation, it had fallen 18 per cent below. With the narrow method, however, the usual second year reduction in yield was practically eliminated; whereas about 15 per cent reduction occurred in the standard and double when the yield of the second year was compared with that of the first.

With respect to per cent of yield as compared to amount of chipping surface used up, the narrow method was markedly superior to the other two methods. In 1916 it showed an increase in yield per inch of height of face of about 40 per cent, and in 1917 of nearly 50 per cent, over the standard.

The productivity of the trees on the narrow area at the end of the second year of operation, even after a long period of dry weather, was very high as compared with that of the trees on the double area. Photographs of freshly cut streaks made immediately after chip-

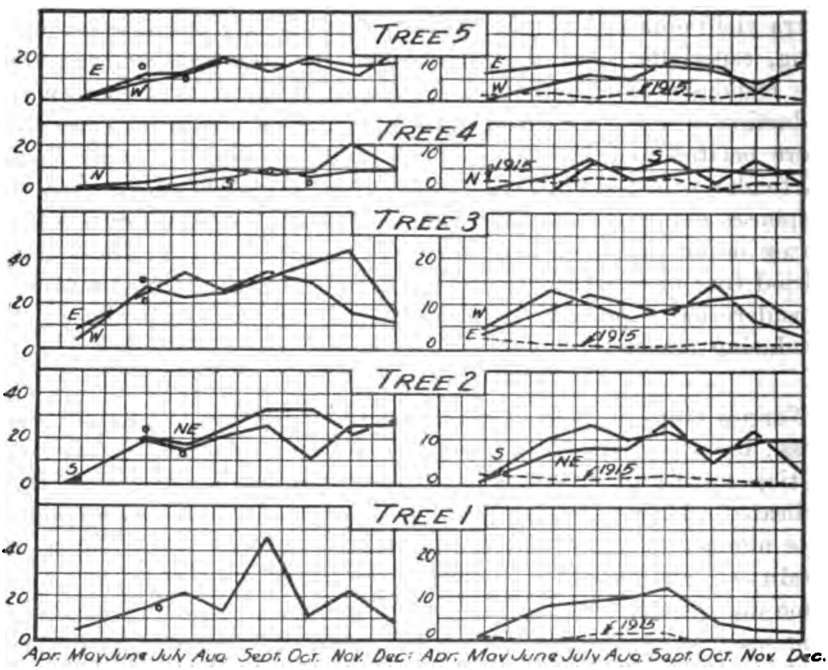


FIG. 5.—Narrow trees, 1916.

Number of tracheids, observed April to December; in 1916, growth ring. ° Summer wood present.

Number of resin centers per unit area (an arbitrary tangential extent; diameter of microscopic field by the width of the annual ring observed). Observed April to December, 1916; in 1916, growing ring; in 1915, completed ring.

ping are shown in Plate III, figures 1 and 2. The abundant exudation of the gum from the narrow-chipped tree shown, even under adverse weather conditions, was so striking that the practical turpentine operator who was managing many crops in that section, and had been very skeptical of the narrow method of chipping, expressed surprise and satisfaction at the excellent condition of the timber. Not all the double-crop trees had "dry-faced" to the extent shown in Plate III, figure 1, but many were in that condition, and the yielding capacity was in general markedly reduced.

Production of resiniferous tissue.—Many more resin passages than are normally present were formed in the wood which developed after wounding. (Figs. 5 and 6.)

In both the 1916 and 1917 rings the greatest number of resin passages per unit area was present in the specimens from the narrow-chipped trees, although the average number present in the 1915 ring, when the timber had not been turpentined, chanced to be smaller (Table 4) than in the case of either the standard or the double specimens. In 1916 the earliest formation of resin passages was also found in the narrow-tract specimens.

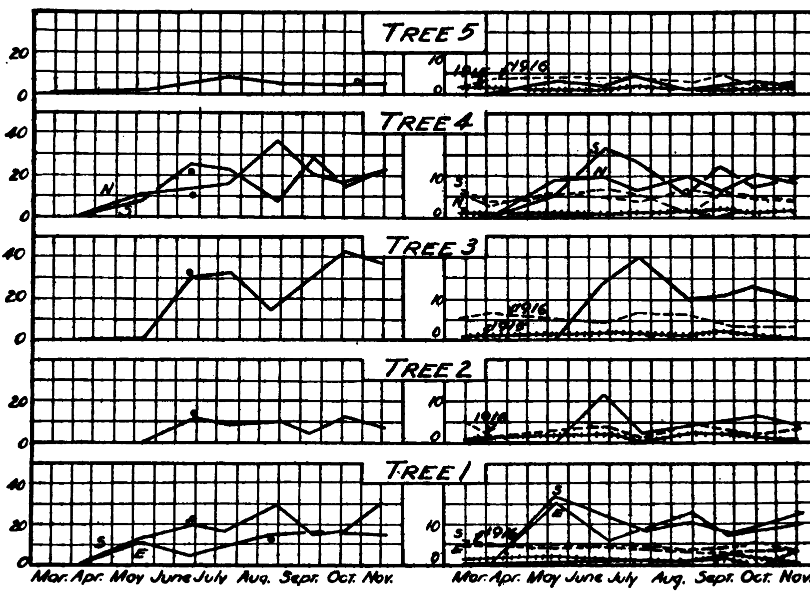


FIG. 6.—Narrow trees, 1917.

Number of tracheids, observed March to November; in 1917, growth ring. ° Summer wood present.

Number of resin centers per unit area (an arbitrary tangential extent; diameter of microscopic field by the width of the annual ring observed). Observed March to November, 1917; in 1915, 1916, and 1917, growth rings. ——, 1915; ——, 1916; ——, 1917.

At the level of the 1917 chipping, fewer resin passages per unit area were present in the 1916 rings than at the lower levels, judging the latter from the specimens studied during their development in the 1916 growing season. This was also true in the other two methods practiced. Some, but not all, of the resin passages induced by wounding were therefore apparently relatively short and appear to have been cut away as chipping progressed up the tree.

The largest resin passages found in the narrow material collected in 1917 were present in the 1916 ring, which was produced during the first year of turpentining. The year 1916 was found, furth

more, to be the best for wood formation, as was shown by the comparative observations made on material showing the 1915, 1916, and 1917 growth rings. The maximum number of resin passages per unit area found in 1917 was not present even at the end of the 1917 season (fig. 7).

Wood formation under narrow chipping.—The width of the annual ring, the time when wood formation begins, and the amount and density of the summer wood, appear to serve as very good criteria of the extent to which the tree is affected by turpentining. A very severe chipping was generally found to be followed by a delay in wood formation and by a very marked reduction in both ring width and percentage of summer wood.

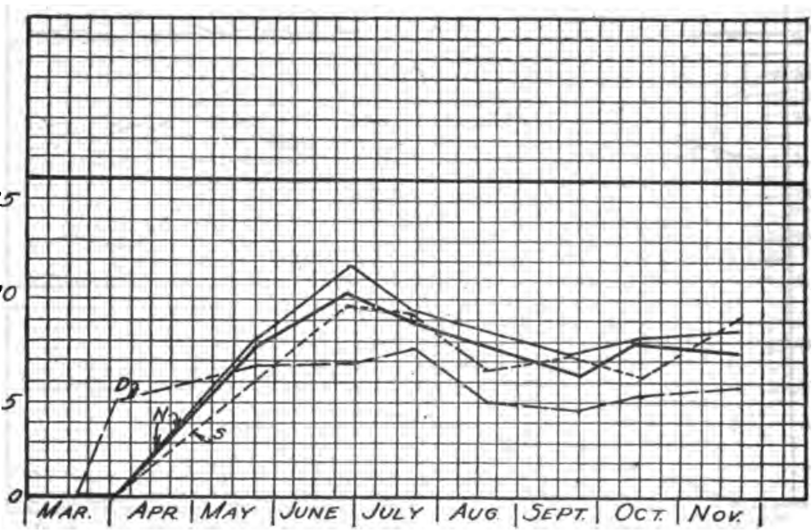


FIG. 7.—Number of resin centers, 1917, based on averages of five trees per crop, as observed monthly. *S*, standard; *N*, narrow (top light line is the average of four normal narrow trees with one dying tree left out); *D*, double.

The wood structure observed in the specimens from the narrow-chipped tract at Columbia, Miss., as shown in Tables 2, 3, and 4, approached most closely the wood formation of the round or unturpentined timber from that section. The width and character of the summer wood were also much nearer normal than in the specimens cut from the standard and double tracts. Hence it might be said that wood formation in general suffered little, or sometimes not at all, from this method of turpentining. In other words, the vitality of the timber and its capacity to respond were less reduced by narrow chipping than by either the standard or the double method. The narrow-chipped trees in many cases (Pl. V, figs. 3 and 4) showed more wood formation in 1917 than in 1916, in spite of the fact that 1917,

PLATE V

In each case the specimens came from the Columbia, Miss., tract and were cut midway between the shoulder and the peak at the streak. The bark is shown at the top of each figure. The two annual rings next the bark (top) were formed during turpentining in 1916 and 1917, respectively. The other rings (below) were formed by the unturpentined timber. In all figures the greatest number of resin passages is present in the rings formed after turpentining.

SPECIMENS FROM THE DOUBLE-CHIPPED AREA CUT NOVEMBER, 1917

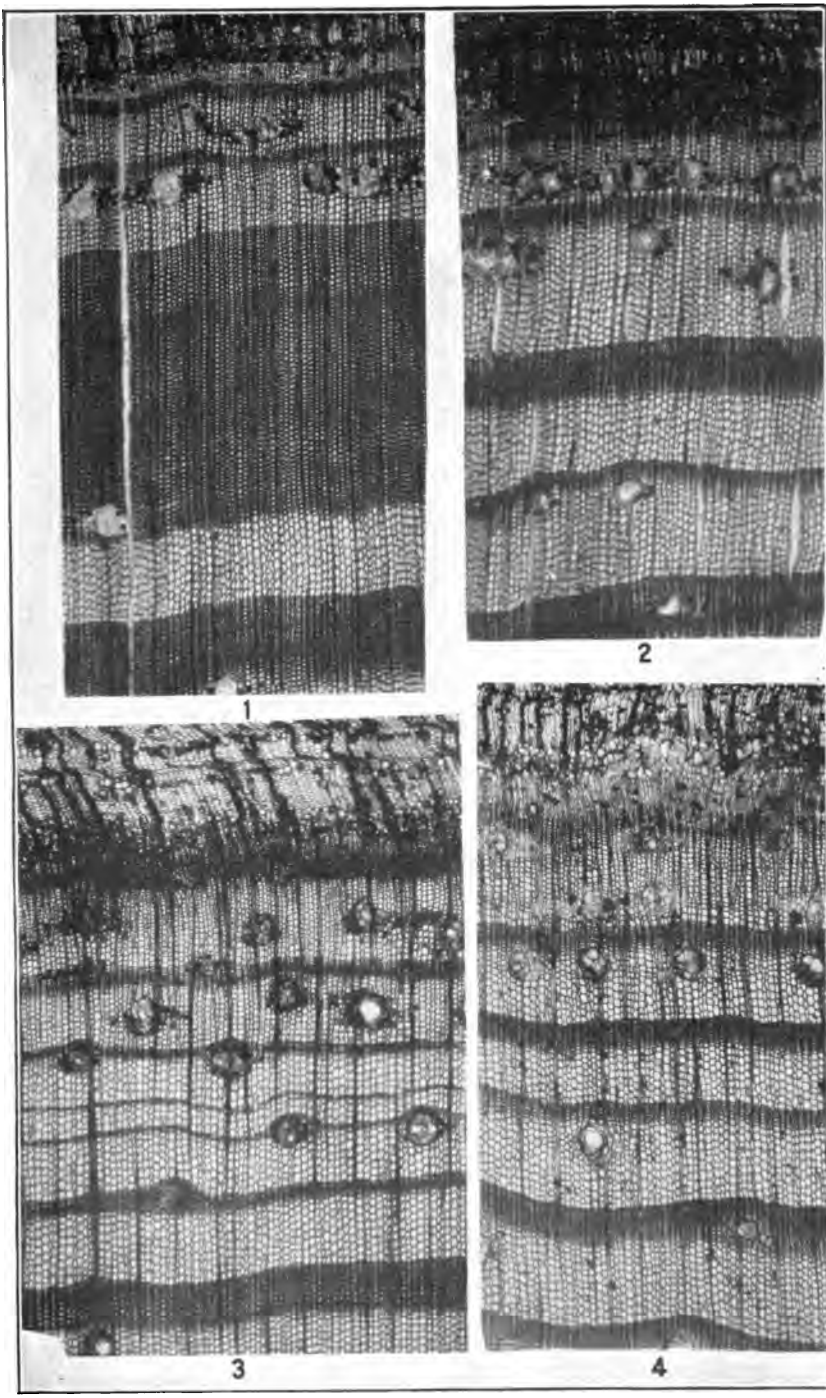
FIG. 1.—Marked reduction in ring width and amount of summer wood accompanying turpentining. This was generally greatest in trees with vigorous wood formation.

FIG. 2.—Tendency to increased ring width in 1916 but reduced summer wood formation. Both ring width and summer wood were reduced in 1917. At this height resin passages are present earlier in the 1917 spring wood than in that of 1916, where probably short resin passages, formed in 1916, have been cut away by chipping.

SPECIMENS FROM THE NARROW-CHIPPED AREA

FIG. 3.—Specimen cut November, 1917. The 1916 and 1917 rings are both wider than the rings formed during the three years previous by the unturpentined timber. The 1917 ring is somewhat wider than the 1916 ring, showing the sustained vitality of the tree in spite of turpentining, and of a poorer season in 1917.

FIG. 4.—Specimen cut July 24, 1917. Here also sustained vigor associated with this rather conservative method is apparent. Note the closed condition of the resin passages.



1 2 3 4

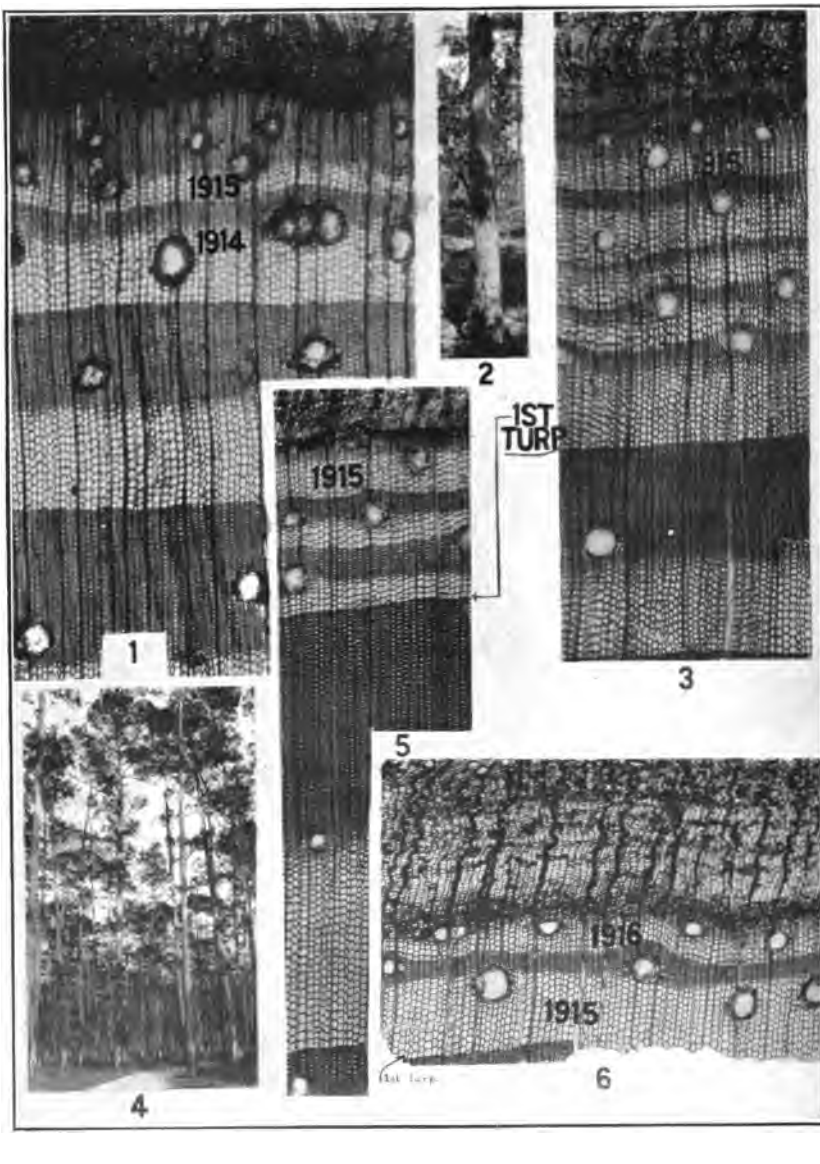

1915
1914
1
2
1ST
TURP
1915
5
3
4
1916
1915
1st turp.
6

PLATE VI

FIG. 1.—Cross section, cut April 24, 1916, from the peak, about 6 feet above the ground, of one of the trees shown in figure 4. The effects of 2 years of heavy chipping are manifested, even in this vigorous timber, by reduction in width of ring and in amount and density of summer wood in the 1914 and 1915 rings. More resin passages than usual are present. The effect of the wound is apparent in the wood formed 6 feet above it in the 1914 ring. No wood formation for 1916 had occurred. Material from near Bogalusa, La.

FIG. 2.—A boxed tree heavily chipped for five years. Wood structure shown in figure 3. Tree near Florida National Forest.

FIG. 3.—Specimen cut from the peak of the tree shown in figure 2, about 8 feet above the ground. The response to turpentining is apparent in reduced wood formation in the five annual rings next the bark (top). The effects in the ring formed when turpentining was first begun were produced about 8 feet above the wound. The specimen was cut in May, 1916. No wood formation for that year was yet apparent.

FIG. 4.—Timber of which the specimen shown in figure 1 is an example.

FIG. 5.—Very heavy chipping was used on this small tree for 3 years. The wood formation was markedly reduced. The specimen was cut May 6, 1916. No wood formation for that year had occurred.

FIG. 6.—Specimen from a conservatively chipped small tree. (Second year of turpentining by the French method.) This tree is from the same locality as the specimens shown in figures 3 and 5. Here, however, 5 or 6 rows of wood cells and one series of resin passages were already formed by May 6, 1916 (top next bark). In 1915, the first year of turpentining, summer wood formation was not reduced in this specimen.

judging from the wood formed by the round timber, was not such a favorable growing year as 1916. Hence it would appear that the narrow method of chipping not only permitted a nearly normal wood production but also a very marked increase in resiniferous tissue.

It is greatly to be regretted that the same operation could not have been continued for at least two years longer, in order that still fuller results from this very promising method might have been secured. In this regard it is of interest to compare the results obtained from an earlier Forest Service experiment, and likewise those from the Florida National Forest, where the chipping is only slightly wider than that actually used on the narrow tract and where this method has been practiced successfully for a period as long as six years. Information clearly indicating the advantages of narrow chipping has also been gleaned here and there from conversations with observing and experienced practical turpentine operators. This evidence, in addition to the positive evidence presented as a result of the present study, definitely points to the importance of further practice of the method, to the end of obtaining conclusive results on a large scale and over a period of four or more years. It is especially desirable that data from narrow chipping on small young timber should be secured.

STANDARD FOREST SERVICE METHOD OF TURPENTINING.

The method of turpentining practiced on the Florida National Forest is designated as the "standard Forest Service method."[24] In the Forest Service leases issued to those who rent timber for the purpose of turpentining, the following requirements were made, subject to inspection by forest officers during the operation of the permit. All unmarked living trees 10 inches and over in diameter, breast-high, were cupped with not more than one face on trees 10 inches to 15 inches in diameter; with not more than two faces on 16-inch to 24-inch trees; and with not more than three faces on any tree. It was customary to make the first streak of a virgin operation when the aprons were placed, some time before the regular chipping began. A No. 1 or smaller hack was required for chipping. Bark bars at least 4 inches wide were to be left between faces. The dimensions of the weekly streak specified were that it should be not more than one-half inch deep (not including the bark) and not more than one-half inch high. In practice the height cut never exceeded one-half inch, and on the areas observed sometimes tended to be slightly less. A total of not more than 16 inches in height

[24] Data obtained chiefly in 1916 and 1917 through the courtesy of Supervisor I. F. Eldredge and Deputy Supervisor E. R. McKee, and in 1921 from Supervisor L. L. Bishop, all of the Forest Service.

of chipping surface or working face (about 32 streaks) was allowed in any one chipping season, so that the operator was at liberty to use more streaks, provided they were less than one-half inch high. (Pl. VII, fig. 4.)

This method was found to give satisfactory and sustained returns even over periods of six or more years. Indeed, timber owners in the vicinity who observed the results thus secured voluntarily abandoned the heavier chipping which they had previously practiced in favor of this method. The question of whether the height of chip used could advantageously be reduced somewhat further—as the results of the narrow chipping at Columbia, Miss., indicated might be the case, at least on the timber of that section—is one needing immediate attention. The yield from the narrow chipping did not show appreciable reduction during the second year, as was generally the case with the crops operated by the standard Forest Service method.

EXPERIMENTS ON THE FLORIDA NATIONAL FOREST.

Very interesting results have been obtained by experiments made on the Florida National Forest near Camp Pinchot in an effort to find a system for working longleaf pine that would produce (at the same cost or, if possible, at smaller cost than that which now is customary in ordinary practice) as high an immediate yield of gum as is now obtained, and also a good sustained yield for a longer period. Some of the methods tested are illustrated in Plate I, figures 5 and 6. Special attention was given to finding a method adapted to application on relatively small, young, second-growth timber. A striking illustration of the effect of heavy as compared with conservative chipping on wood formation and general tree responses was observed when some material from the tract on which the French method of turpentining was being used was compared with specimens from very heavily chipped trees from the same locality on a private tract. Figures 5 and 6, Plate VI, illustrate the relative effects of these methods. Both specimens were cut on May 6, 1916. At that time practically no wood cells had been differentiated in the case of the heavily chipped tree (streak three-fourths inch or more deep and three-fourths to 1 inch in height); whereas a considerable number of wood cells and a number of resin passages had formed in the specimens from the French-chipped area. (Pl. VI, fig. 6.) Moreover, in this latter specimen the ring width and the amount and density of the summer wood formed after turpentining were not reduced, as compared with the conditions found in the round timber. In the case of the heavy chipping, however,

the marked reduction occurring during the three years of turpentining is very apparent, although some allowance must be made for the fact that the greatest reductions in ring width after turpentining generally occurred in the trees with very wide rings, hence at least a part of the reduction noted might be attributed to this characteristic.[25] In general, it may be said that wherever trustworthy evidence is obtained it points to the conclusion that conservative chipping which does not unduly reduce the vitality of the tree, leaving unturpentined trees that are too small, not overcupping, and leaving sufficient bark bars pay in point of yields obtained and in reducing the number of trees which are killed or which dry-face.

EARLY FOREST SERVICE EXPERIMENTS.

Evidence pointing to the advantages of conservative chipping is also to be found in the results from some experiments carried on from 1905 to 1908.[26] The standard chipping of a commercial turpentine company not far from Jacksonville, Fla., was in this case used as a basis for comparison. It was slightly heavier chipping (streaks 0.6 to 0.7 inch deep and 0.51 inch high) than the standard chipping practiced in 1916 and 1917 at Columbia, Miss. Both slash and long-leaf pine were found in the stands of timber used. It was noted that the slash pine produced little or no scrape. The purpose of the work was to determine the results to be obtained from (1) shallower chipping, a reduction of depth of cut from 0.6 or 0.7 inch to 0.4 or 0.3 inch, the shallowest cuts being used on the slash pine; (2) narrower chipping, an intended reduction in height of one-half, which was, however, in practice a narrowing from 0.51 to 0.4 inch; and (3) light cupping, the cutting of fewer faces, and the elimination of turpentining of very small trees with a view to a second turpentining at some future time.

It was reported that considerable difficulty was found in obtaining exact and uniform chipping, because of the change of chippers from time to time on the different crops. Another possible source of some error in the results was the method of determining the relative yields from the different crops by weighing the dip and scrape instead of the turpentine and rosin distilled from it. This method was found to be misleading in the case of the results obtained at Columbia, Miss., where it was found that a high weight of crude gum might be partly due to water mixed with the gum during rainy periods, and that it did not always indicate a proportionally high yield of turpentine and rosin (Table 5).

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[25] A publication is in preparation by the Forest Service on the detailed results and relative yields from the different types of experimental chipping practiced on this tract.

[26] For. Serv. Bul. 90, p. 16.

TABLE 7.—*Early Forest Service experiments—Summary of total yields for 1905, 1906, 1907, and 1908 on the basis of the corrected amounts of dip and scrape (125 chippings).*

[Data from U. S. Department of Agriculture, Forest Service Bulletin 90.]

Crop.	Dip (oleoresin).		Scrape (hardened oleoresin).			Total number of chippings.	Average height of chippings.	Average depth of chippings.	Dead trees at end of second season.	Per cent of stand.	
	Yield.	Increase.	Yield.	Increase.	Decrease.					Long leaf.	Slash.
							Inches.	*Inches.*			
A. Standard chipping of Walkill Turpentine Co.[1]	206,235	....	47,742	....	....	125	0.51	[2] 0.7 to 0.6	121	57	43
B. Shallow chipping	211,911	2.75	44,838	....	6.08	123	.51	[2] 0.4 to 0.3	73	48	52
C. Narrow chipping	214,503	4.01	39,775	....	16.69	124	.40	[2] 0.7 to 0.6	64	46	54
D. Reduced number of faces, larger trees, prospect of back cupping[3]	279,260	35.41	53,915	12.93	....	119	.51	[2] 0.7 to 0.6	58	51	49

[1] Minimum diameter of turpentined trees 6 inches, 2 faces permitted on trees over 13 inches.
[2] Shallower cuts on slash.
[3] Minimum diameter of turpentined trees 10 inches, 2 faces permitted on trees over 16 inches. No more than 2 faces per tree.

A summary of the results obtained is given in Table 7. It is apparent that crop A (standard) showed a successive yearly decrease in yield and the greatest number of dry-faced and dead trees.

Crop B, the shallower chipping, showed in the four years of operation an increase in yield of about 3 per cent over the standard. This gain took place during the last two years of the operation. There was less relative yearly decrease in yields also than in crop A, and less scrape was formed, which fact, the writer pointed out, was in accord with the current idea that deep chipping produced much scrape. From these results it is concluded in Bulletin 90 that there is " no doubt as to the wisdom of shallow chipping."

In sharp contrast to this were the results from an operation visited in 1917 in Mississippi. The type of timber and the method of chipping employed are illustrated in Plate VII, figures 5, 6, and 8. The streak cut was about 0.75 to 1 inch in depth and a scant 0.5 inch in height, and a very high as well as a sustained yield was reported.[27] These trees were characterized by having very wide sapwood. Less than 1 per cent of the trees were lost through death from turpentining. Care and good judgment were exercised in the placing of the cups and in maintaining adequate bark bars between the faces on this timber.

It would appear from the foregoing that the question of the width of the sapwood and the responsive vigor of the timber on any given tract must be considered as of fundamental significance in determining the depth of the streak to be cut. That the resin passages in a

[27] Reported yield of 105 barrels of turpentine per yearling crop and an average of 82 barrels for different ages, including virgin and fourth-year workings.

considerable number of the outer sapwood rings are involved in the yields of gum obtained is evident from the discussion on pages 9 and 10 and from Plate III, figure 2.[28] It would therefore appear that the proportion of the sapwood which it is desirable to expose in chipping probably varies somewhat according to circumstances, and that the range of depth should be more exactly determined by further experiments on different types of longleaf and slash pine timber, especially on young timber, since this is of great future significance.

Crop C, the narrow chipping, did not have as narrow streaks as those cut at Columbia, Miss. Although it was intended that the streaks should be about one-fourth inch in height, it is stated that "in spite of continued urging and the closest supervision, the chippers invariably made the cut wider than was desired. * * * Nevertheless in spite of the failure to reduce the width of the cut as much as desired, a considerable decrease was made." The height of the faces at the end of 4 years on crop A (standard) was 64.3 inches, and on C, 50 inches, or an average height of chip of about 0.4 inch. Under the narrowed chipping this crop showed an increase over the standard which was greater than that secured by the shallow chipping of crop B. Furthermore, less dry-face and dead trees resulted, and about one year of chipping surface (14.3 inches) was gained. These facts, therefore, furnish another instance of successful narrow chipping. How far the streak can further be narrowed with advantage beyond this 0.40 inch and the 0.34 inch obtained at Columbia, Miss., and sometimes obtained in commercial "pulling," is a subject for further experiment.

Crop D, the light cupping at Walkill, Fla., where fewer faces were cut per tree and no tree under 10 inches was cupped, but where the standard streak was cut, gave the highest yield of all the crops and the least loss from dry-facing or death of trees. It should be borne in mind that on the other crops trees with a diameter as small as 6 inches were cupped, and two faces were permitted per tree on timber with a diameter of 13 inches and over. (See Table 7.) As has been recently shown, it is unprofitable from the point of view of the growth in length and diameter of the timber, as well as from that of the yield of gum, to turpentine too small trees by the methods generally practiced in the United States.[29] (See Table 8.)

It was demonstrated clearly both in the Walkill experiment and in Cary's observations (Table 8) that it was of fundamental importance to maintain the vitality and responsive power of the tree. Too large

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[28] This fact was not recognized at the time that the conclusion in regard to shallow chipping was expressed in Forest Service Bulletin 90.

[29] Cary, Austin, "A look ahead" in Naval Stores, published by the Weekly Naval Stores Review, and in "Money is actually lost in working small trees for turpentine and rosin." Naval Stores Review and Trade-Journal. Vol. XXX, Jan. 22, 1921, p. 14, and Nov. 19, Dec. 3, 10, 24, and 31, 1921, and Jan. 7 and 14, and Feb. 4, 1922.

and too numerous faces, which unduly reduce the relative percentage of uncut bark, are unquestionably harmful and unprofitable. The questions of depth and height of streak are intimately connected with the number of faces and the returns obtained, but further work is needed, as has been shown, to fix within narrower limits the range of the most successful depth and height of chipping. It is stated by careful operators that, at the very least, one-third of the bark should remain uncut, and undoubtedly a larger proportion is desirable. The area D at Walkill was so turpentined that it would be possible to work it for a second period (back cup) some time later.

TABLE 8.—*Yield at first dipping from trees of different diameters.*

Diameter breast high (inches).	Set 1.			Set 2.
	Width of face (inches).	Yield (average of 15 trees).	In percentage of 10-inch trees.	Yield.
		Ounces.		*Ounces.*
5				4
6				6
7	7	10	44	8½
8	8	15	67	11
9	9	19	84	14
10	9½	22½	100	16½
11	10	23	102	19
12	10	24	[1] 107	21

[1] 4 trees.

TABLE 9.—*Gain obtained by light cupping as compared with Standard chipping at Walkill, Fla.*[a]

Year.	Dip.		Increase.		Last three years compared to first.			
					A		D	
	A, standard.	D, light-cupped.	Pounds.	Per cent.	Increase.	Decrease.	Increase.	Decrease.
	Pounds.	*Pounds.*						
1905	63,615	73,704	10,089	16				
1906	64,583	84,074	19,491	30	[b] 1½		[b] 14	
1907	43,675	69,286	25,611	58		31		6
1908	34,362	52,196	17,834	52		46		29

[a] For. Serv. Bul. 90, p. 20.
[b] This increase was chiefly due to the fact that in 1905 there were 31 streaks and in 1906, 35 streaks cut.

Because of the gains secured in the first three years of the Walkill experiments, a different experiment was instituted on two crops during the fourth year (1908), which combined both the shallow and the narrow chipping features. "Yearling" or second-year crops were used, and the yields of gum were compared with those from a similar adjacent crop chipped by the standard method. An increased production of about 35 to 38 per cent was secured in this experiment. The "dip" from these shallow and narrow-chipped

trees was also considerably richer in turpentine than the ordinary dip, and fewer dry faces and dead trees were found on these crops. In conclusion, therefore, it may be said that these early Forest Service experiments clearly showed the advantages of certain conservative turpentining methods, which as was at that time felt, were only an indication of what might be accomplished in this direction.

CHIPPING IN THE LIGHTWOOD.

There is a belief current among practical turpentine operators that, to obtain the best yields from turpentining a substantial amount of wood, a high chip should be cut away each week in order to "keep ahead of the lightwood." By lightwood is meant the region above the streak which is more or less saturated with oleoresin. The presence of lightwood is indicated by the difference in color between the surface of the freshly cut streak and that of a wound newly cut in round timber. It may be that the wood is only slightly impregnated with resin, so that the summer wood bands appear somewhat darker than normally, or, on the other hand, that a considerable amount of resin may have soaked into the wood, markedly darkening it, and often making the summer wood appear translucent, especially when the light is allowed to shine through a chip from such a region. An extreme example of this is shown in Plate III, figure 1, in which case the saturation probably occurred as a result of the undue drying out and dying of the overstimulated tree.

Narrow chipping, one-fourth inch to a strict one-half inch in height, will not keep ahead of all lightwood, especially during the midsummer season. For this reason many practical operators were convinced in advance that narrow chipping would fail. However, as has been shown, the results of reducing the height of the chipping speak for themselves in terms of increased yields and sustained vitality of the trees, as indicated, for instance, by the late autumn response shown in Plate III, figure 2, and by the recovery of the tree under turpentining, shown by the amount of wood formation in Plate V, figures 3 and 4.

The following interpretation of the observations made appears to be justified by the results obtained. When a tree is chipped or scarified the living cells in the wood are injured and a strong wound stimulus is given. Oleoresin exudes from the resiniferous parenchyma present. It tends to coat the surface and to cover it with a more or less complete seal, which materially assists in preventing the drying out of the exposed sapwood. Probably most of the parenchyma cells close to the surface of the wound, especially those actually cut, may die. The wound stimulus is undoubtedly greatest in the immediate vicinity of the wound. Its effect appears to be mani-

fested in the increased yields obtained by using the "advance streak." (See pp. 10 to 12.) The effect of the wound on the actively growing tissue is apparent in the tendency of the tree to heal or close the wound. More than the normal amount of parenchyma or resin-yielding tissue is formed, often at the expense of ordinary wood formation. More resin passages or resiniferous parenchyma aggregates were generally produced in a definitely limited region, 8 to 12 inches above the wound, than further above it, as is indicated by the resin passage graphs in figures 1 to 6. Twenty or more inches above the original wound the number of resin passages is notably reduced, as is shown by the 1916 data as compared with those of 1917 in figures 1 to 6. Nevertheless, the wound response giving evidence of the extent to which the stimulus is transmitted, although less marked at a distance, was manifested as far as 7 to 10 feet above the wound. (Pl. VI, figs. 1, 2, 3, and 4.) Both increase in resiniferous tissue, most marked in the transition wood and in the summer wood in the specimens from the higher portion of the tree, and often some reduction in ring width or summer wood formation, occurred in the wood produced after turpentining. The chipping or freshening of the wound is designed to remove the dried and hardened surface of the streak and the unproductive parenchyma cells in order to permit the fresh exudation of the oleoresin, which forms and collects above this sealed surface during the period following the chipping. The chipping also serves to stimulate the living cells to further responses. It appears as if a very narrow chipping should successfully accomplish this purpose. It is obvious that a high chipping cuts away the most intensely stimulated and presumably the most responsive tissue, especially for gum production, in the tree. It is as if a whole organized battery of the tree's forces were wiped out at each stroke of the hack and a new organization had to be mustered afresh in the attempt to respond to the new condition. After a number of such responses, the results of which are cut away and wasted, the tree's resources tend to become more and more exhausted, and the yield of gum and the wood formation are reduced. Many trees under these circumstances become dry-faced—that is, physiologically speaking, their living cells cease production, and they frequently die (Pl. VII, fig. 3); at best the vitality of the timber is too severely taxed to assure the best returns possible.

In brief, then, chipping in the lightwood (progressing up the tree slowly less than one-half inch per week) is to be recommended because: (1) This is performed in the region of maximum stimulation, (2) it conserves chipping surface, (3) it tends to keep the surface from drying out because of the oleoresin saturating it to a greater or less extent, and (4) it has been found experimentally and practically to give sustained yields. Much "pulling" (see Pl. IV,

PLATE VII

FIG. 1.—Well-placed faces. This insures the fullest return from the tree for the labor of operation.

FIG. 2.—Bad placing of faces at the beginning of the operation. This means waste and loss at every stage.

FIG. 3.—The effects at a later stage of placing faces too close together. Note dead and dry face.

FIG. 4.—The beginning of the third year of turpentining, May, 1917, in a conservatively chipped tree. About 16 inches height of chipping surface was cut annually. Standard Practice Florida National Forest.

FIG. 5.—The beginning of the sixth year of turpentining, June 6, 1917, on a well managed commercial operation. In its fifth year about 45 barrels of turpentine were said to have been made from this crop.

FIG. 6.—One tree from the area shown in figure 8. This was the beginning (June 6, 1917) of the second year of this operation. Note chipping $\frac{3}{4}$-inch to 1 inch deep. The sapwood in this case was about 3 inches wide. Thirty-three streaks were cut each year.

FIG. 7.—Excellent opportunities for future turpentining are offered by the good reproduction and rapid growth of slash pine. This tree, 4 feet above the ground, was $5\frac{1}{4}$ inches in diameter and 9 annual rings were present at that height.

FIG. 8.—Stand of old timber, such as is rapidly disappearing. This is characterized by having wide sapwood and by producing very high yields under efficient management. Deep chipping (see figure 6) succeeded in this operation.

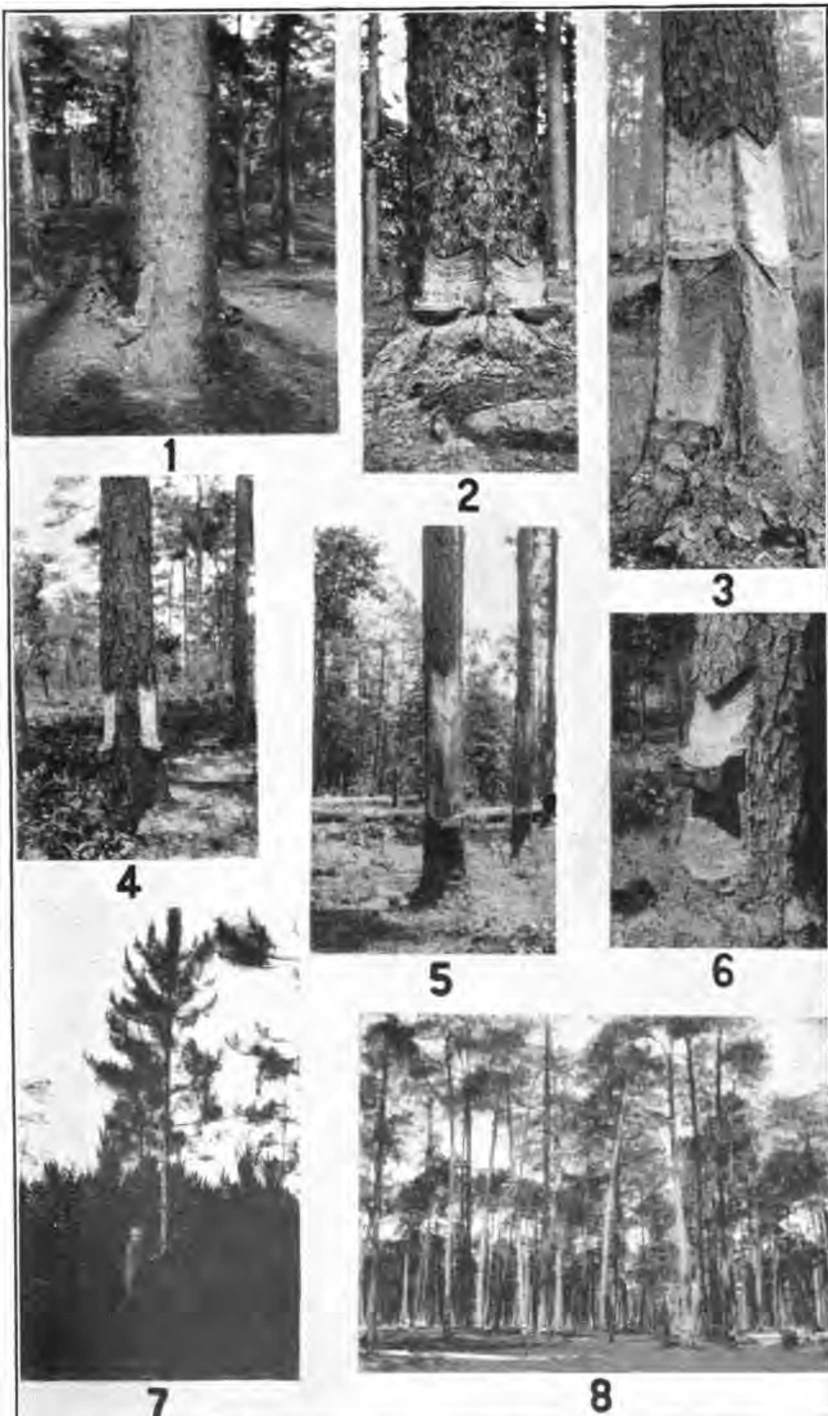
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fig. 6) is so narrow that it is done in the lightwood. The current prejudice against chipping in the lightwood probably arises from the fact that at times the lightwood (Pl. III, fig. 1), especially when it is most conspicuous, may indicate the beginning of dry-facing. Under such conditions the decreased production occurring may be revived to a certain extent by chipping ahead of this lightwood up the tree for several inches, until a region which is less dried out and injured is reached. It is therefore only when it indicates the saturated condition of dead and dried cells, especially the devitalized condition of the resiniferous parenchyma, that the presence of lightwood should be considered detrimental. Such a condition, moreover, is much more likely to occur in high chipping which is designed to keep ahead of the lightwood than in narrow chipping (one-half inch or less) which is done in the region of the lightwood.

SUGGESTIONS FOR FUTURE PRACTICE.

Many of the statements made in the following discussion are not based upon the results from definite experiments, but are derived from the writer's observations made on successful commercial operations or from the statements of experienced operators, or are deductions from the data presented in the preceding pages. They are, therefore, to be considered as suggestions only and are advanced tentatively, subject to further investigation, because in the light of our present knowledge they appear to be beneficial in character.

SIZE OF THE TIMBER.

From the preceding discussion, especially that with reference to light cupping (pp. 29 to 31), it is apparent that it is unprofitable to turpentine very small timber. An excellent example of conservative operation, from the standpoint of present practice in the United States, is the method specified in the Florida National Forest turpentine leases (page 25).

LOCATION AND SIZE OF THE FACES.

One of the most obvious sources of waste in turpentine operations, and apparently a matter which has received relatively little competent attention, is the matter of placing the faces on the trees. Bad practice of this sort, due to carelessness, is only too commonly found. Figures 2 and 3 of Plate VII, illustrating such bad methods, are in sharp contrast with figure 1 of Plate VII, which illustrates the proper placing of faces. This practice of leaving insufficient bark between faces is a fundamental error of the worst sort, since it means waste throughout the operation. Six-inch, or at least 4-inch bark bars should be left between faces, and the width of face should be in pro-

portion to the size of the tree. (See pp. 29 to 31.) Conservative operators recommend leaving one-half, or at the very least one-third, of the bark uncut. Without such provision the tree is unduly injured and its productive power is reduced so that the yield is less or may even fail entirely, as shown in Plate VII, figure 3. The cost of turpentining such trees throughout the operation, or until they die, is, however, just as great in the matter of placing cups and aprons, chipping and dipping, as is the cost in the case of the more productive trees. Such trees are also frequently attacked, some think more often than more healthy individuals, by fungus or insects.[30] Care is required not only with reference to the position of the faces in relation to each other, but also with regard to the way the tree leans, its general shape or curvature, and any special irregularities which may occur. Loss in production of oleoresin is also occasioned by cutting the first streaks too far above the ground. It is of advantage to place the faces as low as the butt conformation of the tree will permit.

The location of the faces with relation to the points of the compass has received some attention but appears to be considerably influenced by variable local conditions. As is shown in figures 1 to 6, the 15 trees selected at Columbia, Miss., where the position of the faces was noted, showed great variability in wood formation, with some tendency toward greater vigor on the south side. From some experiments with western yellow pine (*Pinus ponderosa* Laws.), it was found that an average from the total yields of 50 trees during one turpentining season was 9 per cent greater from the south side than from the north side cups.[31] An experienced operator has advanced the following argument:[32]

It is pretty well settled now that the average pine standing erect has thicker sap on the south side, evidence of greater thrift on that side; then, unless there are conditions that require it otherwise, it would seem to promise a larger yield of gum to so install the cup and chip as to leave as much of this best sap uncut as possible. Make the faces west or southwest, east or southeast. In cupping trees of the size to permit two cups, if the timber is to be cut for lumber before it has time to be recupped (or back cupped), place them opposite, east and west; but if it is expected to be cupped the second time, hang the cups southwest and southeast with 6 inches of unchipped surface between.

CONTAINERS FOR THE GUM.

The destructive method of using a box cut in the tree (Pl. I, fig. 1) to hold the gum has been practically abandoned. In its place are found a great variety of containers or cups of pottery or metal.

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[30] Hopkins, A. D., "The Southern Pine Bettle." Farmers' Bul. 1188, U. S. Dept. Agr., 1921.

[31] Betts, H. S., "Possibilities of Western Pines as a Source of Naval Stores." For. Serv. Bul. 116.

[32] Courtesy of Mr. A. Sessoms, Bonifay, Fla.

Some of these are illustrated in Plate I, figures 3, 5, and 6, and Plate VII, figure 2. They present various advantages and disadvantages. The earthen or clay cups do not rust and discolor the gum as the metal cups that have been used for some time may do, but they are subject to breakage in handling and during freezing weather. Various efforts such as lining metal cups with wood have been made. One of the most successful has been coating old cups with bakelite, which prevents the discoloration of the gum. The argument that the metal cup becomes hotter during warm weather and causes greater evaporation of the gum is advanced by clay-cup advocates. Partly covered cups which reduce evaporation are used in India.

The connection between the cup and the surface of the tree is made by the use of gutters or aprons. (Pl. I, figs. 3 and 6, and Pl. IV, figs 1 and 3.) Efforts have also been made to develop an apronless cup. In order to attach the cups and gutters to the trees, nails are often employed, but these are very undesirable from the point of view of the sawmill end of the operation, for even though they are theoretically all removed, headless or hidden nails may occur and be very destructive if encountered during the process of sawing up the timber. With this in mind, wooden pegs (Pl. IV, figs. 3, 4, and 6) to support the cups or soft lead nails to attach the apron, when the cup is raised, are used by some operators so as to avert possible damage if accidentally left in the tree.

CHIPPING.

Two sizes of hacks are illustrated in Plate IV, figure 2. The hack with the narrow opening or "bill" is a "00," such as was used on the narrow chipping at Columbia, Miss. The other hack is a "No. 2," such as was used on the standard operation by the cooperating company. The method of chipping, a free arm stroke, is illustrated in Plate IV, figure 4. It would be very desirable if a gauged hack could be devised which would mechanically govern the size of the chip cut. The "puller" for cutting a streak on the higher faces is illustrated in Plate IV, figure 6. It is said that "pulling" is more difficult than chipping[33]; the use of the 00 hack and narrow chipping defers the time when pulling need be used. With the puller good narrow chipping may be obtained, as in the case of the double chipping at Columbia in 1917. It is thought to be highly desirable to use a sharp tool and to make clean smooth cuts at regular intervals.[34] Practically, chipping once in seven days has been found to give satisfactory results. The Columbia, Miss., experiments indicated that chipping twice a week was not desirable for long operations.

[33] For. Serv. Bul. 90, p. 19.
[34] In India the smoothness of the face or channel is especially emphasized. The greatest care is taken to remove rough surfaces which would promote the formation of scrape.

DEPTH OF THE WOUND.

The width of the sapwood appears to be very intimately connected with the distance that it is advantageous to cut (radially) into the tree (cf. p. 28). At the present time it can only be stated that a considerable portion of the moist sapwood should be left behind the face. Instances undoubtedly occur in which a very considerable yield of gum may be obtained by making relatively deep cuts, 3/4 inch to 1 inch into sapwood which is as much as 8 inches wide; for a notable yield has been found to come from the resin passages of a number of the outer sapwood rings (Pl. III, fig. 2), not merely from those formed after turpentining. Before chipping more than one-half inch in depth, however, the width of the sapwood should be determined. Some operators judge the amount of sapwood and the yielding capacity of the tree by the roughness or loose, scaly appearance of the bark, as contrasted with the relatively smooth bark found on some trees. No consistently dependable characteristic, however, is known for predicting the productivity of a given tree, for individuals are found to show wide variations.

HEIGHT OF CHIPPING.

The amount of wood removed vertically with the grain at each chipping has been very fully discussed in the preceding pages. It is evident that weekly chipping less than one-half inch in height has been found successful both as to yield and with reference to maintaining the productivity of the trees by not unduly reducing their vitality. The lower limit for the height of chipping has not yet been determined, but in the narrow chipping at Columbia, Miss., an average height of 0.34 inch was actually obtained.

ADVANCE STREAK.

The practice of cutting one streak some weeks before regular chipping begins appears to be advantageous (cf. pp. 10 to 12). Regular winter chipping, however, is considered unprofitable. The advance streak is used in India.

JUMP STREAK.

On many operations, when the cups are raised, a section of uncut bark is left (Pl. VII, fig. 3) so that in driving in the aprons the sapwood layer or conductive tissue will not be completely severed. As a consequence, some chipping surface is lost, but this is reduced to a minimum by changing, as the end of the season approaches, the "set" of the peak, or the angle made by the two streaks at the middle of the face, so that the angle is obtuse.

DESIRABLE PRACTICES.

Ideal chipping should be deepest at the shoulder and shallowest at the peak or most exposed portion of the face, at which point the least normal and most harmful conditions, with respect to the vitality of the trees, are most likely to develop.

Keeping the gum clean means high grades of rosin; hence it is well to cover the cup with a paddle during chipping (Pl. IV, fig. 4), or to equip the "puller" with a chip catcher (Pl. IV, fig. 6), to keep fragments of bark out of the gum during chipping and to avoid filling the cups with trash which will increase the apparent volume of the dip.

DIPPING.

Frequent collecting of the gum or dipping insures higher yields of turpentine.[35] Some advocate scraping off the hardened gum, or scraping with the paddle at each dipping instead of allowing it to remain until the end of the season and removing it all at once as was done in figure 4, Plate I. It is maintained that the latter practice exposes the surface to undue drying, and that harmful cracking and checking may take place. Furthermore, the longer the scrape remains on the tree the greater is the reduction in the amount of turpentine which it will yield. A real reduction of waste may be obtained by using tight dip barrels. On one operation gasoline barrels were employed. Ideal dip containing about one-third more turpentine than usual was obtained by using closed glass cups for holding the gum as it exuded from the tree, but these were found to be very difficult and expensive to operate.

YIELDS.

It would appear as if under proper operating conditions more gum should be obtained at least during the second and third years than during the first, for many more resin passages are present. This, however, is not ordinarily the case in the United States.[36] On the Columbia, Miss., experiment the narrow chipping nearly held its own the second year, but during the first year the total yield, without reference to the amount of chipping surface used, was lower than the yield from the standard.[37] It seems entirely possible that an optimum

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[35] In India dipping is as frequent as chipping. The same worker does both and is paid on the basis of the gum produced. One worker chips (by the French method) about 1,000 faces or channels in 6 days.

[36] Since this was written, information has been obtained from Mr. F. Canning, conservator of forests, India, concerning turpentine operations by the French method (very conservative chipping) on *Pinus longifolia* in the Kumaon Hills in the United Provinces, to the effect that, as a rule, more gum is obtained the second, third, and fourth years than the first. The yield the fifth year is about the same as that obtained during the first.

[37] Data from the Florida National Forest experiments about to be published are also of interest in this connection.

set of operating conditions may some day be found under which the yields will not fall as markedly as is now usual. It has been held that it is in the fourth year that the reduced response of the turpentined trees is most marked. This also may be further delayed or reduced by practicing better methods.

REDUCING THE NUMBER OF CUPS TO THE ACRE.

By applying the rules laid down for conservative chipping (p. 25) the number of cups per acre would be materially reduced. Often a 50 per cent reduction would assure a higher yield. The argument that the cup system has been bad for the trees, based on the fact that the trees have been overcupped, may be true if one considers such operations as one in which 232 cups were hung to the acre, but such a procedure is unproductive and will not long be practiced by clear-sighted operators. The fact that individual pines will survive under excessively abusive treatment is no indication that high total yields over a period of years may be obtained in this way. There is a case on record, for instance, of a tree 9 inches in diameter 5 feet above the the ground which had had two boxes cut in it that were operated for five years. During the third year a cup was also added and the tree continued to produce some gum, although it had all together only 1¼ inches of live bark between the faces. Again, a tree 6 inches in diameter survived turpentining and grew fairly well. Such methods, however, are to be deplored for the same reason that it was not desirable to kill the goose which laid the golden eggs.

REPRODUCTION.

Protecting the turpentined trees and the young growing seedlings (Pl. VII, fig. 7) from fire is of importance to the future of the industry. Very important, also, is the protection of the seedlings from destruction by hogs, which appear to prefer the roots of longleaf pine to those of the less valuable loblolly pine.

SUGGESTIONS FOR FUTURE RESEARCH.

There are still many unsolved problems which are of importance from the point of view both of commercial practice and of fundamental scientific knowledge.

Of immediate significance is the question of the proper turpentining of small timber. The existing second growth, the protected natural reproduction, and the prospective plantations of slash and longleaf pine will be the future source of naval stores. The results presented here were obtained chiefly from large, mature timber. The methods required for the successful turpentining of young trees should have further study, especially with reference to the depth

of chipping advisable in relation to the width of the sapwood. More information, in addition to the results obtained in the Florida National Forest experiments, is desirable in regard to the relative width of face to employ. Which, for instance, is more costly, and which produces higher yields, the use of two small faces or of one large one, or, on larger trees, two large faces or three small ones? In this connection it is important to determine under what circumstances the peak is kept most healthy and productive, since it is at the peak that dry-facing most often begins. The question of the minimum width of bark bars between faces is fairly well determined, but an innovation in the form of leaving a bark bar in the middle of the face, which is practically equivalent to chipping two small faces, has been suggested.

A detailed study of the length of the normal resin passages and of those formed after wounding, made by dissecting the outer surfaces of logs, would furnish information bearing on the desirable height of chipping, and on the matter of maintaining gum production, at least at the level of that obtained during the first year of the operation.

The effect on yields of resting the timber for a year or for a shorter period of weeks or months at some time during the operation might be significant. In one instance it is reported that timber turpentined for two years and rested for a year before continuing the operation gave exceptionally high yields.

More exact information regarding the responses associated with the use of the advance streak is essential in order that this practice should be more fully understood.

The method of using closed cups made it possible to obtain a very high grade of gum, which gave an exceptionally high yield of turpentine, but it was impractical in operation because of the difficulties encountered in freshening the yielding surface and because of the expense of the cups. It seems possible, nevertheless, that some method of covering the cups, such as is used in India, or of protecting the faces or of using borings instead of open faces,[38] might be devised. By such means evaporation might be markedly reduced and production notably increased.

It is highly desirable that some of the conclusions recently obtained in German experiments[39] should be checked upon American species. The filling and the emptying of the resin passages during turpentining is a problem of fundamental significance. The steps in the process by which the tree manufactures the oleoresin are still practically

[38] "To try out the Augur and Glass Holder System." Naval Stores Review, 31: June 25, 1921, p. 10.

[39] Münch, E.: "Naturwissenschaftliche Grundlagen der Kiefernharznutzung." Arbeiten a. d. Biol. Reichsanstalt für Land-u. Forstwirts. 10 Bd.: 1919.

unknown. A more intimate knowledge of the substances of the greatest significance in resin production—as, for instance, the effects of the constitution of the soil—might have a marked influence on future practice. This has been found to be the case with fruit culture, as a result of the work on the effects of the carbon-nitrogen ratio upon vegetative and reproductive responses.[40] Indeed, as has been suggested by Dr. W. D. Bancroft, chairman of the division of chemistry and chemical technology of the National Research Council, who selected oleoresin production as an example of an important present-day problem, the understanding of this subject appears to involve cooperative work by a botanist, a microscopist, an organic chemist, and a colloid chemist. Much valuable information on oleoresin has already been collected by the Bureau of Chemistry and by different units of the Forest Service, and with the timber on the Florida National Forest available for experiment, the opportunities for carrying on further research are exceptionally good. That the future need in this direction is recognized and that plans (in the carrying out of which microscopically obtained data can unquestionably be of service) are being formulated, is indicated in the following statement of Col. W. G. Greeley, Forester:[41]

> One of the things which must be worked out as part of our general progress in forest conservation is a system of extracting gum turpentine which will make this industry and its valuable commercial products a permanent resource of the Southern States. We must develop a plan for tapping second-growth timber, somewhat along the lines used in France but adapted to commercial requirements in the United States, under which this can be a continuous forest industry, obtaining yields of gum from the same trees for 20 or 30 years, right up to the time when they are cut and converted into lumber. Without some method of this nature the gum turpentine industry will soon cease to exist. I am hopeful that the Forest Service can extend the instructive experiments in various methods of conservative chipping and cupping which you[42] have already initiated on the Florida National Forest in order to work out completely a plan of tapping second-growth timber without injury which can be adopted commercially by the owners of pine land throughout the South.

SUMMARY.

The results of this work and of the other earlier and current experiments of the Forest Service clearly demonstrate that those methods which conserve the vitality of the tree and its responsive power, under stimulation such as is given by turpentining, insure the greatest production of oleoresin. The process of turpentining is not merely a draining out of the gum already formed; it is a collection of the oleoresin constantly being manufactured by the tree.

[40] Kraus, E. J., and H. R. Kraybill, Oregon Agric. College, Exper. Station. Bulletin 149, 1918.

[41] For. Serv. Bul., Jan. 3, 1921.

[42] That is, Florida National Forest organization.

This production of gum by the tree is greatly increased as a result of the stimulation of the wound or face cut.

The institution of cupping, in place of boxing, made it possible to eliminate the unnecessary injury to the tree caused by cutting the box, and hence was a marked advance in the direction of improved operation.

The proper placing of faces with reference to the size and conformation of the tree, and the maintenance of bark bars of sufficient width between faces, are matters of fundamental importance, which too often are neglected in practice. These matters if not cared for involve waste and loss throughout the operation.

The fact that it is unprofitable to turpentine too small trees, at least by present commercial methods, has been demonstrated beyond question.

The practice of cutting a streak in advance of the regular season's chipping on a virgin or first year operation appears to be productive of an increased early yield, which is of practical importance. This effect, as has been clearly shown, is not produced by the induced resin passages, formed at once as the immediate result of the streak, but presumably is due to the wound stimulus given to the resiniferous tissue already present.

The following effects of turpentining on the structure of the wood have been pointed out:[48]

The structure of the annual rings of the wood formed before turpentining was not found to be visibly affected as a result of the turpentining, although the activities and responses of the living parenchyma cells in the outer layers of the sapwood already present in the immediate vicinity of the wound were undoubtedly stimulated by it. It was demonstrated that the resin passages of a considerable number of these outer sapwood rings contributed a very significant portion of the yield of oleoresin.

The structure of the wood produced after wounding was considerably modified, especially in the region immediately above the face. The effect in a tangential or circumferential direction was relatively slight, being hardly noticeable at a distance of 2 or 3 inches to the side of the wound. In all material the number of resin passages formed was greatly increased. The resin passages were formed earlier in the ring than normally. They varied from about the same diameter as that of the normal resin passages to rarely larger and frequently smaller diameters. The response to the wound stimulus, particularly in respect to the increased number of resin passages formed, was observed to be greatest within about 1 foot above the

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[48] See also Gerry, E., "Proper Methods of Turpentining," Sci. Am. Sup. 2176, Sept. 15, 1917; and Gerry, E., "Production of Crude Gum by the Pine Tree," Naval Stores, p. 147, 1921.

wound. It was also registered in the wood produced 6 to 9 feet vertically above the wound. At this point the resin passages were fewer than near the streak, but, nevertheless, were more numerous than in the round timber. The resin passages in the specimens studied were observed in both the open and closed condition, as is shown in the illustrations. Although this increased number of the resin passages, formed after wounding, is an important factor in securing a high yield, they are not, as has been shown, the only or possibly even the chief source of the gum.

Provided the size of the timber and the faces and their location have been properly cared for, the method of chipping which is intimately connected with these features is also of fundamental significance. Characteristic effects on the structure of wood, resulting from different methods of chipping, were determined and fully described in the discussion of the microscopic investigations made.

HEAVY CHIPPING.

Heavy chipping (more than one-half inch in height and more than three-fourths inch in depth) or overcupping tends to produce the following undesirable results in the wood formed after turpentining.

1. Delay in the beginning of wood formation.
2. Delay in the formation of resiniferous tissue.
3. Reduction in width of annual rings.
4. Reduction in amount and thickness of walls of the summer wood.
5. Tendency to develop resiniferous parenchyma at the expense of other wood cells.
6. Death of a relatively high percentage of trees and tendency to produce dry-face.
7. Markedly reduced yield from year to year.

CONSERVATIVE NARROW CHIPPING.

Conservative chipping, of which the narrow, as practiced at Columbia, Miss., is an example, produced results in direct contrast to those from heavy chipping. The optimum methods of turpentining are still to be determined, but in the light of our present knowledge, the application of the following specifications would appear likely to produce the nearest approach to ideal operation that has thus far been attained.

No tree under 10 inches in diameter, breast high, should be cupped.

One-half, or at the very least one-third, of the total circumference in the neighborhood of the faces should be covered with uncut bark. Bark bars, at the minimum about 6 inches wide, should be left between faces.

Chipping should progress up the tree at the rate of not more than one-half inch a week. In experiments in which chips of an average height of 0.40[44] to 0.34[45] inch were actually cut, a higher sustained yield was produced than in comparable workings in which the chip averaged one-half inch high. In the case of the double chipping at Columbia, Miss., an average height of chip of 0.32 inch was obtained with a 00 hack in 1916, and an average 0.26-inch chip with a puller during 1917. During the second year these trees, under this treatment, showed a smaller relative reduction in yield of turpentine, when compared to the first year yield, than did the half-inch chipping (standard). Using such a narrow streak means chipping in the lightwood or region of maximum stimulation, at least for a part of the season. It is yet to be determined whether the height of the chip can be further reduced.

Sufficient experiments to determine the most advantageous depth of chipping have not been carried out. It appears probable that the significant factor in this case, however, is the width of the sapwood, since, as has been shown, a considerable yield is obtained from many of the outer sapwood rings. A layer of healthy moist sapwood should always be present behind each face to maintain at the maximum the vital activities of the sapwood layers exposed at the streak. With wide sapwood and deep chipping (about three-fourths inch) very high yields may be obtained.

The advantages to be gained by the practice of conservative narrow chipping were shown to be the following:

1. Higher yields (40 to 50 per cent) per inch of height of chipped surface.

2. Higher sustained yields—that is, less reduction in yield from year to year, approaching the optimum condition, confidently to be expected, when the yields of subsequent years will surpass that of the first year.

3. Total annual yield approximating or even surpassing the yield from heavier chipping.

4. Little reduction, on the average, below the wood formation of the round timber, either in amount or quality.

5. Very high production of resiniferous tissue. This, for a given year, was markedly greater about one foot above the early streaks made that year. Hence narrow chipping enables the operator to reap the full benefit from this region of maximum stimulation and response by the practice known as chipping in the lightwood instead of wasting the wood containing the greatest number of resin passages by cutting it away with high chipping.

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[44] Early Forest Service Experiments, page 27.

[45] Narrow chipping, Columbia, Miss., page 21.

6. Low rate of death of trees from turpentining and the production of few dry faces, hence less degrade of lumber due to pitch saturation or to infection at the face area.

7. Responsive vigor not reduced, as is shown by (*a*) the early formation of wood and resiniferous tissue; (*b*) the increases in diameter growth found even under turpentining; (*c*) the formation of the summer wood, which also occurred earlier in the narrow than in the standard and double chipped timber at Columbia, Miss.; and (*d*) a relatively very high total production during the second year of operation, especially since this was sustained as is shown, for instance, late in the season even after a severe drought, when neighboring crops showed a comparatively poor exudation of gum.

8. Greater ease in operating, once the chipper becomes accustomed to the method, since less wood is removed and the chipping period can be prolonged and the pulling period deferred, because the amount of surface chipped yearly is less.

FREQUENCY OF CHIPPING.

From the results obtained with the double chipping at Columbia, Miss., it was concluded that the yield obtained did not show a sufficient increase to offset the additional cost in the case of turpentine operations lasting for a considerable number of years. For a very short operation, when it is planned to turpentine for a period of perhaps two years before cutting the timber, double chipping might possibly be practiced regularly, or perhaps with greatest advantage for a limited period during the height of the producing season. The microscopic study of the material from the double tract showed that this method exerted a decidedly detrimental influence on wood formation and on the general vitality of the timber; and that it used up chipping surface to the same extent as ordinary commercial practice.

STANDARDS FOR ESTIMATING THE EFFECTS PRODUCED BY DIFFERENT METHODS OF CHIPPING.

In estimating the responses of the timber turpentined by the various methods of operation used at Columbia, Miss., the wood formation, especially the width of ring and the amount of summer wood produced by unturpentined trees growing in the same locality under the same conditions, was determined as a basis for judging the effects of turpentining on the wood structure. The best diameter growth and summerwood formation for the three years 1915, 1916, and 1917, were found in the round timber in 1916. Hence marked decreases in the wood formation of the turpentined timber for that year could be attributed directly to the effect of the wounding. De-

creases in 1917 were less indicative, but increases were more significant, since normal diameter growth was relatively low in that year.

It was observed that, regardless of the method used, the response, after turpentining, of trees with very narrow annual rings often was to produce much wider rings than before; whereas the trees with exceedingly wide rings and very heavy summer wood often showed marked reduction in the wood formed after turpentining.

A tendency toward more vigorous responses was observed on the south side of trees, as contrasted with the north side.

Very great variation in wood formation and productive power was observed in individual trees in the same environment. No satisfactory means was found, however, of positively determining in advance the productive power of a tree. Marked variations in the wood formation on different sides of a tree, at different parts of the streak, and at different heights, were noted. The study of specimens obtained month by month at different heights was therefore more enlightening in many respects than observations made only at the end of the season.

MISCELLANEOUS OBSERVATIONS.

No consistent relation between width of ring and number of resin passages resulted from an analysis of the data available on this subject.

No indication of a structure corresponding in any way to the "resinogene Schicht" of Tschirch was observed.

The first formation of wood in the region of the trunk where turpentining is carried on was observed, in 1916 and 1917, to take place not earlier than April 8 to 10; and from that time on in different trees it continued until by the middle of May it had begun in practically all trees. Wood cells or tracheids for the most part formed before resiniferous tissue.

The first formation of resiniferous tissue occurred between the middle of April and the end of May.

Finally, turpentining gives an additional product and profit from the forest before the trees are cut into lumber. This gain may be obtained, at least in the case of well-managed, large, mature timber, without reducing its strength, or appreciably degrading the lumber. The inch or so of the outer sapwood involved in the process of turpentining is removed in the slabs and edgings when the logs are cut up. Poor turpentining methods which kill or dry-face the timber, may produce some degrade due to pitch-streak formation, decay, or excessive insect attack, but this is for the most part unnecessary. The fact that many lumber companies are turpentining their own timber is also a pertinent argument for the practice.

Turpentining a given tract should, however, be planned far enough in advance of the cutting of the trees to insure the obtaining of the full advantage of at least a four to six year operation, instead of the sawmill demand forcing the timber to be cut at the height of its gum-producing power.

Many other problems, involving the further development of needed improvements in practice, and also many related to a better understanding of the imperfectly known physiological processes fundamental to oleoresin production, await investigation.

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